

Review and Summary of Pre-Wet Methods and Procedures

Final Report



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16. Abstract Pre-wetting is an important tool in the toolbox of winter road maintenance (WRM) operations. This research project collected all available and recent information regarding pre-wetting practices through a comprehensive literature review, an online survey of WRM practitioners, interviews and case studies of nine selected agencies, and outreach to six identified equipment manufacturers/distributors. Through the synthesis of current and best practices, the project resulted in preliminary guidelines or recommendations, mainly based on trial-and-error and field experience, instead of systematic and scientific investigations. There have been many success stories of pre-wetting practice by transportation agencies in northern climates. The pre-wetted material stays on the surface longer, has less bounce and scatter, and resists traffic action. The case study agencies also reported that pre-wetting allowed them to achieve the specified level of service more quickly. A pre-wetting rate of 8–12 gal/ton is effective and 8–16 gal/ton is reasonable for increasing the speed and total ice melting capacity of solid salt and reducing the snow-pavement bond. Practitioners have reported that higher pre-wetting rates (than 10 gal/ton) can achieve better operational results, thus reducing the amount of granular salt needed. For trucks equipped with pumps to make salt slurry, a higher pre-wetting rate (30 to 50 gal/ton) can be achieved. A higher application rate should be used when there is a lower pavement temperature or a more severe snow event. All survey respondents reported the use of on-board systems to apply liquids to solids. Agencies may face initial resistance to pre-wetting from operations staff or other stakeholders, but training and information dissemination coupled with effective field trials will gradually mitigate concerns and build rapport. The project also identified knowledge gaps or research needs relevant to pre-wetting practice.					
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Review and Summary of Pre-Wet Methods and Procedures

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Executive Summary

The goal of this research was to compile a summary of pre-wetting practices including equipment, materials, methods, and application rates and identify the history of successes and failures that have contributed to the current practices. Pre-wetting is an important tool in the toolbox of WRM operations. This research project collected all available and recent information regarding the pre-wetting practice, through a comprehensive literature review, an online survey of WRM practitioners, interviews and case studies of nine selected agencies, and outreach to six identified equipment manufacturers/ distributors. Through the synthesis of current and best practices, the following conclusions can be drawn. Note that these should be treated as preliminary guidelines or recommendations because the pre-wetting practices have been mainly based on trial-and-error and field experience, instead of systematic and scientific investigations.

- 1) There have been many success stories of pre-wetting practice by transportation agencies in northern climate, even though few of them produced systematic investigations. The pre-wetted material stays on the surface longer, has less bounce-and-scatter, and resists traffic action. For example, one field test showed 80% of pre-wetted salt remained on a road surface after 100 vehicles traveling at 38 mph, while only 15% remained for dry salt. Pre-wetting also provides faster activation of rock salt turning into a brine and accelerating the ice melting process. Field experience suggested typical savings of 25–30% less salt required when using the pre-wetted salt. Pre-wetted abrasives can reduce the amount of material applied by as much as 50% compared with dry abrasives in low temperatures. Field tests showed that the pre-wetted sand resulted in higher friction improvement (as high as 187%) than dry sand when used at the same application rate. The case study agencies also reported that pre-wetting allowed them to achieve the specified LOS quicker.
- 2) On the most reasonable materials: Salt brine (23 wt.%) is the most commonly used liquid for pre-wetting of rock salt and abrasives, and 30 wt.% MgCl₂ and 32 wt.% CaCl₂ are popular alternatives in low temperatures when salt brine becomes less effective. Other additives can be admixed into chloride brines to reduce the corrosivity of the brine or enhance the snow/ice control performance of the pre-wetted salt. Beet juice has been increasingly used as a performance enhancer of salt brine, typically at 30% by volume, for pre-wetting and deicing.
- 3) On the most reasonable liquid-to-solid pre-wetting rates: In theory, only enough liquid to wet every particle of a dry material is required for pre-wetting. The actual rate to achieve this wetting will vary with the particle size distribution of the solid, but 8–12 gal/ton is effective and 8–16 gal/ton is reasonable for increasing the speed and total ice melting

capacity of solid salt and reducing the snow-pavement bond. Practitioners have reported that higher pre-wetting rates (than 10 gal/ton) can achieve better operational results, thus reducing the amount of granular salt needed. For trucks equipped with pumps to make salt slurry, a higher pre-wetting rate (30 to 50 gal/ton) can be achieved. A higher application rate should be used when there is a lower pavement temperature or a more severe snow event. A greater pre-wetting application rate may be needed for abrasives than for salt.

- 4) On the most reasonable procedures and equipment: All survey respondents reported the use of on-board system to apply liquids to solids. The truck-mounted brine spraying equipment is typically comprised of a liquid tank, pump system, spray bar, and controller. Some manufacturers sell pre-wetting systems to be added to in-use spreaders and some sell spreaders integrated with pre-wetting abilities. The most effective way to deliver pre-wetted salt is a cross conveyor while the truck travels at 25 mph, and the spreader ground speed on interstates could go up to 35 mph. Most survey respondents apply the pre-wetting liquids just prior to the spinner, followed by in the chute and at the auger (esp. to obtain a slurry mixture). Pre-wetting on top of the chain (before the salt enters the chute) or in the auger works better for salt to achieve the saturation condition than at the spinner, although this can cause corrosion issues.
- 5) On the common delivery systems: Pre-wetting equipment can involve a variety of liquid delivery systems and spreader configurations. The easiest on-board pre-wetting process is spraying or streaming liquid material onto the spinner plate, where the spinner plate, liquid application nozzles, and controller capabilities can be modified or adjusted to achieve the optimal efficiency of the pre-wet process. The solid material can be pre-wetted as it passes over the spinner casting disk. Another type of on-board pre-wetting process entails the spreading of solid and liquid materials simultaneously before they hit the road. The liquid emitter tubes have a directional valve to control the spray pattern. Also, the liquid emitter tubes revolve in sync with the spinner disk thus creating a more uniform mixing of liquid and solid materials as they are applied. It is desirable to include an agitator in the feed mechanism to break down the solid material supplied to the delivery roller.
- 6) On the type of pumps to use: The majority of the survey respondents reported that their agency switched from electric pump to hydraulic pump so as to allow for the application of higher rates. Hydraulic pumps are also preferred by some DOTs because they are easy to calibrate or less prone to corrosion issues (and thus require less maintenance or spreader down time). But the Washington State DOT prefers electric pumps and has successful user experience of approximately 10 years; relative to hydraulic pumps, these electric pumps provide more volume and are less expensive, easier to maintain, and easier to adjust. Some DOTs now use gravity feed system for pre-wetting, so that no pumping is needed and no more concern over the maintenance of pumps. Generally, old trucks are equipped with electric pumps that provide a flow rate capacity of about 5–7 gallons per minute (GPM), whereas newer trucks equipped with hydraulic-

driven pumps that provide a flow rate capacity of 10-18 GPM (which is needed for slurry applications).

- 7) On the type of spreader configurations: The survey respondents reported the following types of spreader configurations commonly used by their agencies: 1) zero velocity spinner/spreader; 2) front discharge with conveyor chain; 3) wheel track sprayer; 4) tailgate spreader; 5) v-box spreader with chain conveyor; 6) rear discharge spinner; 7) center discharge spinner with V-hopper; and 8) saddle tank gravity to spreader spinner. *Zero-velocity spreaders and pre-wetting techniques yielded bare pavement in half the time of standard methods, while reducing salt use by 70% and salt cost per mile by about 50%.* However, there is no good way to spread sand with zero-velocity spreaders.
- 8) On the nozzle type, hose size and screen size: The fan nozzle is the most common used type, mainly because it can lead to a more uniform coverage. Stream nozzles are also used by many agencies, because they allow the liquids to be more focused on solids and thus are perceived as more effective. For pre-wetting, only 1–4 nozzles are needed for the solids on the chute or spinner, and the most common hose size is 1-inch in diameter. The screen size of the pre-wetting equipment ranges from 16 mesh to 80 mesh, and preferably as small as possible (without being easily clogged).
- 9) On the reliability/maintainability/safety issues of on-board systems: The pre-wetting equipment can be at least just reliable as other WRM equipment, given regular maintenance and calibration. Yet, the reliability of pre-wetting equipment depends on operators or circumstances and there could be issues with liquid delivery pumps. It is crucial to keep pre-wetting equipment maintained, especially at the end of the season as well as calibrating at the beginning of season. System flushing and nozzle/screen cleaning are required at least twice per season.
- 10) On the implementation of pre-wetting practice: Agencies may face initial resistance to pre-wetting from operations staff or other stakeholders, but training and information dissemination coupled with effective field trials will gradually mitigate concerns and build rapport. Some obstacles for agencies transitioning to pre-wetting may include cost, equipment, capacity, logistical challenges, and worker availability.
- 11) On the recent developments: New on-vehicle tools (e.g., zero-velocity spreaders and modified spinners) facilitate precise and effective applications of both solid and liquid materials. Yet another new technique is the use of pre-wetted fine graded salt, i.e., the spreader mounted on the truck crushes or mills salt in ordinary size into fine size, which results in a substantially longer durability of the salt on pavement (especially on dry or moist road surfaces).

During the past decade, the most common change by transportation agencies is the increased use of liquid. As a result, the liquid application equipment has also changed, such as larger pre-wetting tanks, increased pump size, and increased flow rate. Some agencies are also switching the pre-wetting location from the spinner to the chain or auger. Most of the responding agencies use technologies such as RWIS, AVL or MDSS to

aid in determining when and how to use pre-wetting. Most equipment manufacturers reported having advanced systems for data recording capabilities through the use of plow cams, GPS, and ground surface temperature thermometers. Many systems can monitor routes and track material distributed. These advanced technologies allow for the ability to gather data and adjust application rates as needed.

For the *case study agencies*, all of them have changed their pre-wetting practices since first implementation based on increased understanding, support, and better equipment and technologies. They have increased capacity, better training, and positive community backing, and most have also upgraded equipment to include larger capacity, bigger volume and hydraulic pumps, spray nozzles, ground speed sensors, and live bottom v-boxes.

Through the synthesis of the information collected in this project, the following knowledge gaps or research needs can be identified.

- 1) There is a lack of scientific and quantitative knowledge on how various factors influence the costs and benefits of pre-wetting practice, for typical road weather scenarios. Most survey respondents reported that pre-wetting can lower the total cost of WRM operations, in terms of materials, equipment, and labor. However, the majority of them have not yet conducted the cost-effectiveness or cost-benefit analysis.
- 2) The scientific or quantifiable evidence of effectiveness underlying the specific pre-wetting operation, especially the pre-wetting application rate, is lacking and there is an urgent need to study and optimize both the appropriate pre-wetting rate of liquid-to-solid and the appropriate application rate of the pre-wetted salt for the typical road weather scenarios. The optimal rates are likely a function of climatic conditions, pavement surface conditions, traffic volume and speed, particle size distribution of solid material, type of pre-wetting liquid, methodology for pre-wetting, equipment type/configuration, groundspeed of the spreader vehicle, etc. Looking to the future, such knowledge gaps should be addressed by experiments in the laboratory as well as field operational tests to be designed and executed during Phase II.
- 3) For Phase II, one needs an experimental design that is statistically valid and practically feasible, in terms of field evaluation of the impacts of different pre-wetting equipment/configurations, materials, and rates on the effectiveness of pre-wetting. A multi-state testing program is needed to provide a reasonable representation of diverse road weather scenarios, equipment, liquid and solid products, etc. seen in the Northern States. Field testing should be conducted to assess the effects of various pre-wetting liquid-to-solid application rates and specific liquid products to: (1) reduce bounce and scatter, (2) reduce overall salt application rates, (3) improve friction, (4) reduce the time to regain bare pavement, (5) reduce corrosion to metals on equipment, and (6) increase the longevity of winter traction materials under variable speed traffic.

Chapter 1. Introduction

The goal of this research was to compile a summary of pre-wetting practices including equipment, materials, methods, and application rates and identify the history of successes and failures that have contributed to the current practices. Pre-wetting refers to the application of liquid products, such as brines, to solid material (primarily salt, abrasives, or a combination of these) prior to the pre-wet material hitting the road. Pre-wetting, in combination with optimal vehicle speeds, reduces the bounce and scatter loss that causes dry material to disperse beyond its desired location. Pre-wetting can also help activate the ice melting, penetration and undercutting mechanisms that help break up snowpack for subsequent mechanical removal. While literature is available from reports and articles about pre-wetting, a significant amount of information resides within personal experience at the state and municipal level and even within manufacturers' research and development activities. Combining information from all these sources was a key objective of this research to provide guidance to maintenance districts looking to add pre-wetting to their toolbox of winter maintenance operations or improve their current practices. To achieve our goal, this research produced a comprehensive summary of pre-wet materials, equipment, and methods.

The need to synthesize the relevant best practices in a guidance document may be rooted in the fact that winter road operations have significantly improved over the past decade or two. In addition to growing experience with pre-wetting practices, there have been significant advances in chemical products and delivery equipment and systems in recent years. For example, pre-wetting equipment can involve a variety of wet liquid delivery systems and spreader configurations. Some systems rely on electric pumps and others use hydraulic pumps. Additional factors include nozzle selection, optimum pressure, screen size, hose diameter and flow meter design. New on-vehicle tools (e.g., zero velocity spreaders, modified spinners, and other delivery mechanisms) facilitate precise and effective applications of both solid and liquid materials. This necessitates a new look into the methodologies and application rates currently used for pre-wetting practice.

Furthermore, all agencies in recent years have faced challenges of sharply reduced budgets, loss of experienced personnel, aging and worn vehicles and equipment, environmental regulation and mandates, occasional shortages of materials, additional workload due to growth and development, and omnipresent public scrutiny. In this context, this project sponsored by Clear Roads is much needed to enable best practices, i.e., "do more with less."

This research project encompassed five tasks including: (1) a review of pre-wetting practice for winter road maintenance, (2) online survey of Clear Roads member states and international transportation agencies, (3) interviews and case studies of agencies' successful and optimal

practices in the areas of pre-wetting materials, equipment, and methods, (4) Outreach to equipment manufacturers/distributors for information on equipment specifications, manufacturers' operation instructions, and any research or tests performed, and (5) the final synthesis report.

Chapter 2 presents the results of Task 1, i.e., a literature review of pre-wetting practice for winter road maintenance operations. We conducted the comprehensive search of past and current research pertaining to pre-wetting, looking at both national and international sources.

Chapter 3 presents the findings of Task 2, i.e., summary of pre-wetting survey results. Using an online survey, we collected data from transportation agencies and manufacturers from across the U.S. and Canada, identifying a wide range of practices from diverse geometric and climactic regions. The survey garnered 34 respondents from 25 states and Canada and captured practitioner insights and detailed information about pre-wetting rates, materials, and equipment. This valuable data serves to bridge gaps identified in Task 1.

Chapter 4 presents the findings of Task 3 (Interviews/Case Studies of Pre-wetting). For Task 3, nine case studies were conducted, representing six states, two city agencies, and one county agency, i.e., Idaho Transportation Department, Illinois McHenry County, Lexington, MA, Massachusetts Department of Transportation (DOT), Farmington Hills, Michigan, Montana DOT, North Dakota DOT, Oregon DOT, and Vermont DOT. The participating agencies represent a diverse combination of jurisdiction, population, and miles and types of roadways maintained during snow and ice events. These case studies provided examples of successful and optimal practices and provided sufficient detail for agencies to begin adopting new practices or adapting existing practices.

Chapter 5 presents the findings of Task 4 (Outreach to Equipment Manufactures/Distributors). In Task 4, we identified six manufacturers/distributors, i.e., Henderson, SnowEx, Epoke (reported by distributor Wausau Equipment Co.), Hilltip Corp., Monroe Truck Equipment, and New Leader Manufacturing (which manufactures Hi-Way brand equipment). The goal of this task was to identify the pre-wetting equipment capabilities and options available for DOTs looking to incorporate pre-wetting.

Chapter 6 presents the conclusions of this project based on the findings from prior tasks (with the focus on best practices) and identifies knowledge gaps relevant to pre-wetting practice for winter road maintenance operations (i.e., gaps to be addressed during Phase II).

This synthesis report concludes with appendices of detailed data collected.

Chapter 2. Literature review: pre-wetting practice for winter road maintenance operations

1. Introduction

Winter road maintenance (WRM) operations, a.k.a, snow and ice control operations, are one of the most critical responsibilities of state/provincial departments of transportation (DOTs) and local departments of public works (DPWs) in nearly all the continental U.S. and Canada. Such maintenance operations include anti-icing, plowing, deicing, sanding, and snow fence construction (Du et al., 2019). Generally, a combination of these tactics is utilized by transportation agencies to ensure the safety, mobility, and reliability of roadways during winter weather. The focus of this work is to review the publications from recent decades to better understand the practice of pre-wetting practice used in WRM operations.

Pre-wetting refers to the application of liquid deicer products, such as brines, to solid material (primarily salt, abrasives, or a combination of these) on the truck as the solid material is spread on the roadway. Pre-wetting can be used for either anti-icing or deicing (Du et al., 2019). Pre-wetting, in combination with optimal vehicle speeds, reduces the bounce-and-scatter loss that causes dry material to disperse beyond its desired location (Cui and Shi, 2015; O’Keefe and Shi, 2005).

Pre-wetting is most commonly done with on-board equipment either by spraying the solids or mixing liquid with solids just before spreading on the road. Less common alternatives include purchasing manufactured pre-wet materials; pre-wetting at the stockpile (more commonly referred to as pre-treating instead of pre-wetting); or pre-wetting as spreader trucks are loaded (also a version of pre-treating). However, this chapter focuses mainly on the on-board pre-wetting practice, because it is one where most innovations have occurred.

The on-board spray system is the most effective method for pre-wetting in which liquid material is applied onto solid material just before solid material is applied onto roadways (Kaur, 2018). By using this method, the solid material is more uniformly coated with liquid material. Moreover, in the on-board system, only the required amount of solid material is pre-wetted and no left-over pre-wetted materials is produced as compared to the pretreating method.

The pre-wetting practice improves performance by accelerating the process of solid chemical particles going into solution and keeping the material on the pavement by reducing the loss or waste from bouncing, blowing, sliding, and traffic action where dry material is forced to leave the wheel paths by the vehicle tires (TAC, 2013; Gerbino-Bevins, 2011; Burtwell, 2004). The pre-wetted material stays on the surface longer, bounces less (due to greater “staying power”), and resists traffic action. For example, one field test showed *80% of pre-wetted salt remained on a road surface after 100 vehicles traveling at 38 mph*, while only 15% remained for dry salt

(Evans, 2, 2008). Moreover, it was reported that pre-wetted rock salts or other chemicals could reduce the initial waiting time (the time it takes before the particles started to penetrate and melt ice and snow) or even melt precipitation immediately (Trzaskos and Klein-Paste, 2020). An increase in snow and ice melting capacity may be seen due to the combination of solid and liquid chemicals being used (Alger and Haase, 2006). These indicate a significant potential for reduction in chemical use in pre-wetting, with typical savings of 25–30 percent commonly reported (Burtwell, 2004; Maine DOT, 2003). For example, field testing of pre-wet salt in Ontario over two winter seasons demonstrated *pre-wet salt application rates can be 30% less than dry salt* (Radaelli and Dizaji, 2017).

Recent advances in chemical products and delivery equipment and systems for pre-wetting can involve a variety of liquid delivery systems and spreader configurations. Some systems rely on electric pumps and others use hydraulic pumps. Additional components to consider include nozzle selection, optimum pressure, screen size, hose diameter and flow meter design. New on-vehicle equipment (e.g., zero velocity spreaders and modified spinners) facilitate precise and effective applications of both solid and liquid materials. Because WRM operations have significantly improved over the past decade or two, there is a need to synthesize the relevant best practices in a guidance document. This necessitates a new look into the methodologies and application rates currently used for pre-wetting practice. To achieve this goal, a comprehensive summary of pre-wetting practice is needed.

2. Methodology

The literature search began with a detailed search of articles, reports, and other publications using keyword search of databases including: TRB's TRID online (<http://trid.trb.org/>); Google Scholar; Canada Institute for Scientific and Technical Information; Transport Research Laboratory in UK; National Winter Service Research Group in UK (<http://www.nwsrg.org/>); and Washington State University libraries. Research conducted in Canada, Europe, Japan, and other international sources was reviewed wherever available, along with the ongoing research and existing documents published by the DOTs, Clear Roads, Pacific Northwest Snowfighters (PNS) Association, university transportation centers, FHWA, NCHRP, ACRP, APWA, AASHTO, etc.

The literature review included the most common practices, innovative techniques, and trends related to pre-wetting equipment, systems and materials, pre-wetting application rates of liquid-to-solid, application tactic (anti-icing before a storm or deicing in conjunction with plowing), and the appropriate methodology and equipment to use under various road weather scenarios (temperature ranges, relative humidity, storm conditions, operating conditions, etc.). The literature search also covers any scientific studies of bounce-and-scatter, salt activation, and corrosion inhibition related to pre-wetting.

3. Pre-wetting materials

The most commonly used solid materials in the pre-wetting practice are dry salt and abrasives (Fay et al., 2015). Salt brine is the most commonly used liquid material to pre-wet dry salt or abrasives (Kaur, 2018). Sodium chloride (NaCl) has a eutectic temperature of -6°F at 23.3% concentration (Nixon and Williams, 2001). The term “eutectic temperature” is defined as the lowest freezing point for a chemical at a corresponding eutectic concentration (Keep and Parker, 2000). This can be seen through a phase diagram of the NaCl–water system, as shown in Figure 2.1. The dip in the figure called the eutectic point corresponds to the lowest freezing point at the optimal concentration. The freezing point of the brine decreases as the concentration increases until the eutectic concentration is reached. After that, the freezing point increases sharply with an increase in the solution’s concentration. The different phases of brine solution, separated by the eutectic curve in Figure 1 can be summarized as: above the curve–melting action; below the curve–refreezing due to colder temperature; left of the curve–refreezing due to not enough salt; and right of the curve–crystallization due to too much salt (Salt Institute, 2016). In practice, the *larger difference between eutectic temperature and ambient temperature, the faster the snow and ice melt* (Fischel, 2001). Therefore, the ideal liquid chemicals used for pre-wetting are the solutions with lower eutectic temperatures that more effectively melt snow and ice at lower temperature (Kaur, 2018). The eutectic temperatures for the common chloride pre-wetting materials are shown in Table 2.1.

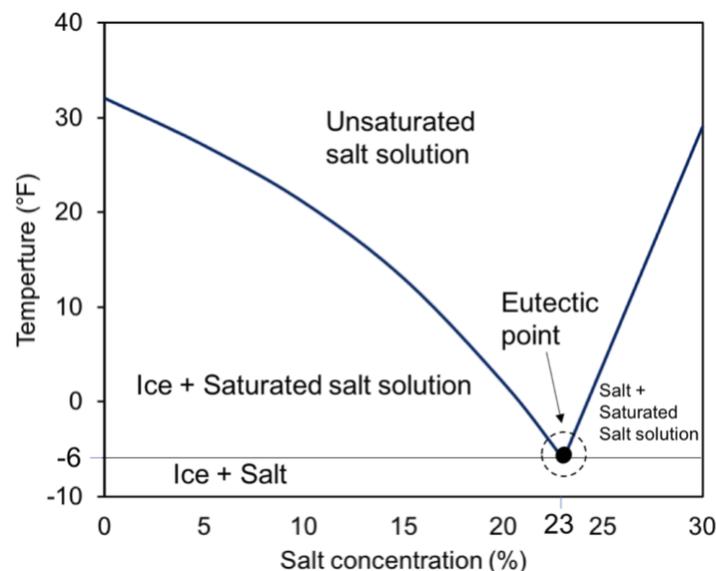


Figure 2.1. Phase diagram of the NaCl–water system (Du et al., 2019)

Chloride brines can be diluted by precipitation and melting of snow, resulting in an increase in the freezing point due to the decrease in concentration (Salt Institute, 2016). As a result, chloride chemicals cease to be effective before the eutectic temperature is reached. For

instance, NaCl is rarely used by DOTs when the ambient temperature is below 15°F, even though its eutectic temperature is -6°F (Nixon and Williams, 2001). Thus, it is necessary to introduce the effective temperature, which is used to describe the lowest temperature for chemicals in practical use (Fischel, 2001). Nixon and Williams (2001) suggested that the lowest effective temperature of salt is the temperature on the phase diagram corresponding to a solution concentration that is half of the eutectic concentration (11.65% and 18°F for NaCl). This is true by and large, but this relationship depends on the dilution ratio occurring typically within the first hour of salt application. The 1:1 dilution ratio assumption could become inaccurate as the pavement temperature fluctuates beyond the typical range, or as additives are incorporated into NaCl. Note that for chemicals other than NaCl, the effective temperature may not correspond to 50% of the eutectic concentration, because the dilution of the chemical depends on the amount of ice melt as a function of time, pavement temperature, etc. The lowest practical pavement temperatures for common chloride chemicals as reported by many sources are also shown in Table 2.1.

Table 2.1. Eutectic and lowest effective working temperatures of chloride-based pre-wetting materials (Du et al., 2019)

Materials	Eutectic temperature (°F)	Lowest working temperature (°F)	Reference
NaCl	-6	15	Salt Institute (2003), MN PCA (2016), MnDOT (2010), Ketcham et al. (1996), Fischel (2001) Norem (2009) Nixon (2008)
		17.6	
		18	
MgCl ₂	-28	-10	MN PCA (2016) Resource Concepts Inc (1992) MnDOT (2010) Salt Institute (2003), NH DoES (2016), Fischel (2001)
		-4	
		0	
		5	
CaCl ₂	-60	-31	Resource Concepts Inc. (1992) Fischel (2001) Salt Institute (2003), NH DoES (2016), MN PCA (2016) Nixon (2008) MnDOT (2010)
		-25	
		-20	
		-5	
		0	

Compared with salt brine, more effective pre-wetting materials, such as magnesium chloride (MgCl_2) and calcium chloride (CaCl_2), work faster in ice melting when pre-wetting solid salt, especially at cold temperatures (Koefod et al., 2015; Koefod, 2017). Field studies in Ontario of *pre-wetted salt with liquid CaCl_2 and MgCl_2 , as expected, outperformed dry salt* in most test cases, with CaCl_2 outperforming MgCl_2 (Fu et al., 2006). However, there is a study showing that *pre-wetting salt with liquid MgCl_2 requires more overall salt than pre-wetting by liquid NaCl* , to achieve the desired effect (Vaa, 2004a). In this study, the author also found that *liquid MgCl_2 as a pre-wetting material provided better friction on the road than liquid NaCl* . Relative to NaCl , MgCl_2 and CaCl_2 feature eutectic temperature of -28°F and -60°F , at the concentration of 23% and 30%, respectively (Kaur, 2018). Both the eutectic and lowest effective working temperatures of MgCl_2 and CaCl_2 are listed in Table 2.1.

Other liquid chemicals, such as corrosion inhibitors and agricultural by-products, have served as additives to salt brine (Fu et al., 2012; Kaur, 2018). A case study focusing on the beet molasses-based materials indicated that agricultural by-products were generally more expensive than normal chloride chemicals (Fu et al., 2012). However, *admixing agricultural by-products into salt brine has been found to lower freezing point, provide enhanced ice melting capacity, reduce corrosivity, and/or extend action time* once applied on pavement (Fischel, 2001; Kahl, 2002; Muthumani et al., 2017). For instance, agricultural by-product additives in NaCl brine for pre-wetting solid salt is reported to significantly reduce the corrosivity to carbon steel (Muthumani and Shi, 2017). Some chemicals commonly used as food additives, such as disodium succinate hexahydrate and sodium propionate, have also been studied and recommended to be used as pre-wetting materials due to their better performance in snow melting, less corrosion to metal, and less negative impacts to natural environment (Takahashi et al., 2018, 2017).

One alternative to salt at very cold temperatures is the use of abrasives. Dry abrasives are applied onto roadways to increase friction coefficient, especially at low temperatures when chemical action is slow and in conditions where strongly bonded snow and ice is hard to remove. Generally, increase in friction coefficient due to the use of abrasives features a short-term effect, resulting from the fact that traffic will rapidly disperse abrasives (Levelton Consultants, 2007). Additionally, abrasives have their limitations such as negative impacts on water quality and aquatic species, air quality, vegetation, and soil and the cost of cleanup (Staples et al., 2004). As a result, many U.S. agencies are reducing or eliminating the use of dry sand. For pre-wetting abrasives, liquid chemicals used to pre-wet abrasives melt just enough of the snow pack to allow the abrasives to embed into the surface (Nixon, 2001) to provide a rough sand-paper-like surface. *Pre-wetted abrasives can also reduce the amount of material applied by as much as 50% compared with dry abrasives in low temperatures* (Williams, 2003). Field tests showed that the *pre-wetted sand resulted in higher friction improvement (as high as 187%)* than dry sand when used at the same application rate (Usman et al., 2017).

An alternative to liquid chemicals for pre-wetting abrasives has been demonstrated in some Scandinavian countries and Canada is heated water (Dahlen and Vaa, 2001a). Typically, pre-wetting sand with hot water is used for deicing operation as the pre-wetted sand adheres immediately to packed snow or ice (Figure 2) and stays on the road surface for a longer time (Perchanok et al., 2010). Spreaders are equipped with tanks that heat water to 203°F and then the heated water is mixed with sand at the spreading disk (Perchanok et al., 2010; Vaa, 2004b; Wisconsin TIC, 2005). The heated abrasives can melt a small quantity of snow or ice as the material hits the pavement (Nixon, 2001). Hot water sanding (HWS) technology prevents the sand from being blown away from the road surface by traffic and reduces the quantity of salt and sand needed, compared with conventional methods. A test conducted in Norway showed that pre-wetting abrasives with hot water maintained higher friction even after the passage of 2,000 cars (Dahlen and Vaa, 2001b). However, special equipment and operational and safety issues must be addressed when implementing this new technology (Nixon, 2009). For example, the fog cloud formed around the spinner during the HWS operation could significantly reduce visibility, resulting in a safety concern for following traffic (Perchanok et al., 2010), as shown in Figure 2.3.



Figure 2.2. Deicing operation using pre-wetted sand by hot water (Perchanok et al., 2010)



Figure 2.3. Fog cloud following the hot water sanding spreader (Perchanok et al., 2010)

4. Pre-wetting application rate of liquid-to-solid

In theory, only enough liquid to wet every particle of a dry material is required for pre-wetting. The actual rate to achieve this wetting will vary with the particle size distribution of the solid, but 8–12 gal/ton is common. *Pre-wetting at rates of 8–30 gal/ton of sand or other abrasives has proven effective* (Kummer, 2005). To minimize bounce-and-scatter, *the suggested application rate for pre-wetting was 10–12 gal/ton* (Blackburn et al., 2004). Ice melting test on much higher pre-wetting rates for salt (32– 38 gal/ton) shows that *there is no benefit when increasing pre-wetting rates to such a high value, suggesting that pre-wetting rates higher than that needed for salt–ice contact/coating are unnecessary* (Koefod et al., 2015). In practice, it has been found that *10 to 12 gallons of 23 wt.% of NaCl solution will be sufficient for 1 ton of dry materials of coarse gradation* (Blackburn et al., 2004). However, a case study consisting of field tests at three sections of Ontario highway reported that *the pre-wetting application of 40 gal/ton resulted in higher friction and lower overall material application than application rates of 10 or 20 gal/ton* (Usman et al., 2019).

Suggested application rate for the most common liquid pre-wetting materials (NaCl, MgCl₂, and CaCl₂) to pre-wet the solid material is shown in Table 2.2. These ranges are a synthesis of practices derived from guidelines and experiences used by various state DOTs (Kaur, 2018). It should be noted that a larger value in the application rate range should be used when there is a lower temperature or a more severe snow event. Field tests have suggested that pre-wetting is not necessary at relatively high pavement temperatures and a low application rate is preferable if pre-wetted salt is used under this condition (Sooklall et al., 2006). Table 2.3 lists the guideline for the use of pre-wetted salt in various road and weather conditions.

Table 2.2. Pre-wetting application rate of liquid-to-solid (Kaur, 2018)

Pre-wet material	Pre-wetting material	Application rate (gal/ton)
Salt	23% NaCl	5 – 15
	22% MgCl ₂	5 – 13
	30% CaCl ₂	6 – 10
Sand	23% NaCl	20 – 22
	22% MgCl ₂	13 – 20
Salt-Sand mix	23% NaCl	9 – 16

Current pre-wetting practices, especially the application rate of liquid- to-solid, lack scientific or quantifiable evidence of effectiveness. Most practices have been primarily based on trial-and-error or observations by the agencies. A laboratory test confirmed that the pre-wetting application rate range of 8–16 gal/ton was reasonable for increasing the ice melting capacity of

solid salt and reducing the snow–pavement bond (Akin et al., 2018). However, a limitation of this test is that it did not mimic the bounce-and- scatter; as a result, the pre-wetted salt did not show better friction performance than dry salt. Field tests conducted in Ontario utilized visual assessment to compare the performance between applying pre-wetted sand at a lower rate and applying conventional dry sand at a higher rate (Usman et al., 2017).

Table 2.3. Guideline for the use of pre-wetted salt in various road and weather conditions (Hanke et al., 2019)

When/What vs. How	Anti-icing			De-icing		
	Dry road surface	Moist road surface	Wet road surface	Super cooled or rain on cold pavement	Thin ice or snow	Thick ice or snow
Pre-wetted salt	Not allowed	Can be used	Suitable	Suitable	Suitable	Suitable

Our recent laboratory tests confirmed that the pre-wetting liquid-to-solid application rate in the range of 8–16 gal/ton (33–67 L/ton) is reasonable for increasing the speed and total ice melting capacity of solid salt (Zhang et al. 2021). Furthermore, pre-wetting significantly reduced snow–pavement bond strength but did not increase friction more than dry salt (Zhang et al. 2021). It should be cautioned that there are key limitations in the laboratory tests, i.e., bounce-and-scatter from realistic application speeds was not included and only slow, light traffic was simulated.

5. Pre-Wetting Equipment

The effectiveness of pre-wetting practice depends on the selected materials and, just as importantly, on the treatment technique (Cui and Shi, 2015). Michigan DOT examined the effect of different delivery systems on the amount of salt bounce-and-scatter (Michigan DOT, 2012), and concluded that the most effective way to deliver pre-wetted salt is a cross conveyor while the truck travels at 25 mph.

The truck-mounted brine spraying equipment is typically comprised of a liquid tank, pump system, spray bar, and controller. Usually, tanks for pre-wetting operation are smaller than those used in direct brine applications for anti-icing and deicing operations (DRISI, 2019). Pre-wetting systems are available as either tailgate mount or hopper-side mount tanks (Figure 4). For the hot water sander, a tank that heats the water is usually mounted on the tailgate of the

vehicle and the pre-wetted sand is applied using a side-discharge spreader located between the front and rear wheels of the vehicle (Perchanok et al., 2010).



Figure 2.4. Hopper-side mount pre-wet tank and liquid tank for direct liquid application (North Dakota DOT)



Figure 2.5. Hot water sander (Perchanok et al., 2010)

Pre-wetting equipment can involve a variety of liquid delivery systems and spreader configurations. Some systems rely on electric pumps and others use hydraulic pumps, and in practice both systems require calibration and constant maintenance (Stantec Consulting, 2012). Spreader configurations include nozzle selection, optimum pressure, screen size, hose diameter and flow meter design. The easiest on-board pre-wetting process is spraying or streaming liquid material onto the spinner plate, as shown in Figure 2.6. The spinner plate, liquid application nozzles, and controller capabilities can be modified or adjusted to achieve the optimal efficiency of the pre-wet process (DRISI, 2019). The solid material can be pre-wetted as it passes over the spinner casting disk. Another type of on-board pre-wetting process entails the spreading of solid and liquid materials simultaneously before they hit the road (Figure 2.7). The liquid emitter tubes have a directional valve to control the spray pattern. Also, the liquid emitter tubes revolve in sync with the spinner disk thus creating a more uniform mixing of liquid and solid materials as they are applied (Chebot et al., 2015).



Figure 2.6. Basic on-board pre-wetting operation (Minnesota DOT)

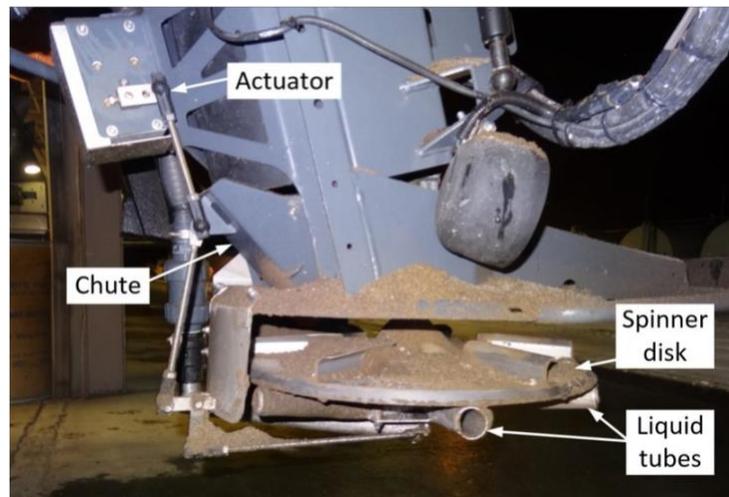


Figure 2.7. Liquid tubes mounted to the bottom of the spinner disk (Caltrans)

New on-vehicle tools (e.g., zero-velocity spreaders and modified spinners) facilitate precise and effective applications of both solid and liquid materials. Zero-velocity spreaders, as shown in Figure 8, apply material rearward to offset the forward velocity of the vehicle and ultimately reduce bounce-and-scatter loss (TAC, 2013). Using a zero-velocity spreader with pre-wetted salt increases the percentage of applied material retained on the road when applied at high speeds (TAC, 2013). A research reported that *zero-velocity spreaders and pre-wetting techniques yielded bare pavement in half the time of standard methods, while reducing salt use by 70% and salt cost per mile by about 50%* (Mitchell et al., 2006). However, there is no good way to spread sand with zero-velocity spreaders (TAC, 2013).



Figure 2.8. Zero-velocity spreader equipped on a truck (Thompson Engineering Company, 2014)

In recent years, a new technique emerges in some Scandinavian countries, such as Norway, is the use of pre-wetted fine graded salt (Hanke et al., 2019), as shown in Figure 9. The spreader mounted on the truck is able to crush or mill salt in ordinary size into fine size. Compared with ordinary pre-wetted salt, salt application with fine graded pre-wetted salt has a substantially longer durability, especially on dry or moist road surfaces. Actually, the time the fine graded salt stays on the pavement can be as long as brine (Hanke et al., 2019).



Figure 2.9. Spreading of pre-wetted fine graded salt in Norway (Hanke et al., 2019)

6. Conclusions

This extensive review of several recent decades of literature highlights current practices, innovative techniques, and trends related to materials, the liquid-to-solid application rate, and the equipment for on-board pre-wetting. Based on the literature review, the key findings are summarized as follows.

- 1) The pre-wetted material stays on the surface longer, bounces less, and resists traffic action. For example, one field test showed 80% of pre-wetted salt remained on a road

surface after 100 vehicles traveling at 38 mph, while only 15% remained for dry salt. Field experience suggested typical savings of 25–30 percent less salt required when using the pre-wetted salt. Pre-wetted abrasives can reduce the amount of material applied by as much as 50% compared with dry abrasives in low temperatures. Field tests showed that the pre-wetted sand resulted in higher friction improvement (as high as 187%) than dry sand when used at the same application rate.

- 2) Salt brine is the most commonly used liquid for pre-wetting. The other two chloride-based materials, $MgCl_2$ and $CaCl_2$, are popular alternatives in low temperatures when salt brine becomes less effective. Other additives (e.g., corrosion inhibitors and agricultural by-products) can be admixed into chloride brines to reduce the corrosivity of the brine or enhance the snow/ice control performance of the pre-wetted salt.
- 3) A recent trend for pre-wetting abrasives is the use of hot water, especially in the very cold regions. How water sanding help melt just enough of the snow-pack so that the abrasives stay on the road longer. But this technology could significantly reduce visibility, resulting in a safety concern for following traffic.
- 4) Pre-wetting salt with liquid chemicals can be used in both anti-icing and deicing operations, while the hot water sanding is used only in the deicing operation.
- 5) In theory, only enough liquid to wet every particle of a dry material is required for pre-wetting. The actual rate to achieve this wetting will vary with the particle size distribution of the solid, but 8–12 gal/ton is effective and 8–16 gal/ton is reasonable for increasing the speed and total ice melting capacity of solid salt and reducing the snow-pavement bond. A higher application rate should be used when there is a lower pavement temperature or a more severe snow event. Field tests have suggested that pre-wetting is not necessary at relatively high pavement temperatures and a low application rate is preferable if pre-wetted salt is used under this condition. A greater pre-wetting application rate may be needed for abrasives than for salt.
- 6) The truck-mounted brine spraying equipment is typically comprised of a liquid tank, pump system, spray bar, and controller. The most effective way to deliver pre-wetted salt is a cross conveyor while the truck travels at 25 mph.
- 7) Pre-wetting equipment can involve a variety of liquid delivery systems and spreader configurations. The easiest on-board pre-wetting process is spraying or streaming liquid material onto the spinner plate, where the spinner plate, liquid application nozzles, and controller capabilities can be modified or adjusted to achieve the optimal efficiency of the pre-wet process. The solid material can be pre-wetted as it passes over the spinner casting disk. Another type of on-board pre-wetting process entails the spreading of solid and liquid materials simultaneously before they hit the road. The liquid emitter tubes have a directional valve to control the spray pattern. Also, the liquid emitter tubes

revolve in sync with the spinner disk thus creating a more uniform mixing of liquid and solid materials as they are applied.

- 8) New on-vehicle tools (e.g., zero-velocity spreaders and modified spinners) facilitate precise and effective applications of both solid and liquid materials. *Zero-velocity spreaders and pre-wetting techniques yielded bare pavement in half the time of standard methods, while reducing salt use by 70% and salt cost per mile by about 50%.* However, there is no good way to spread sand with zero-velocity spreaders.
- 9) Yet another new technique is the use of pre-wetted fine graded salt, i.e., the spreader mounted on the truck crushes or mills salt in ordinary size into fine size. Compared with ordinary pre-wetted salt, salt application with fine graded pre-wetted salt has a substantially longer durability, especially on dry or moist road surfaces. Actually, the time the fine graded salt stays on the pavement can be as long as brine.

The scientific or quantifiable evidence of effectiveness underlying the specific pre-wetting operation, especially the pre-wetting application rate, is lacking and there is an urgent need to study and optimize both the appropriate pre-wetting rate of liquid-to-solid and the appropriate application rate of the pre-wetted salt for the typical road weather scenarios. Looking to the future, such knowledge gaps should be addressed by experiments in the laboratory as well as field operational tests.

corrosion inhibitors, with the most common scenario being that the liquid is inhibited and the solid salt is pre-wet with inhibited liquid.

3. On-board pre-wetting

All 34 survey respondents completed the winter maintenance operation section. All survey respondents reported that their agencies use an on-board system to apply liquids to solids. From the survey responses, the most frequent location where the pre-wetting occurs is “at the spinner”, followed by “in the chute” and “at the auger”, as shown in Figure 3.2. One trend in recent years is that more agencies are trying to retrofit their trucks to apply pre-wetting at the auger to obtain a slurry mixture of solid material and liquid material. In this way, it can reduce the splatter caused by pre-wetting material “at the spinner” and increase mixing of materials. Oregon DOT reported their recent experience of pre-wetting the salt on top of the chain before the salt enters the chute and this minimized the risk of salt dust plugging the nozzles. Oregon DOT auger sanders apply the pre-wetting liquid above the auger in the hopper.

To clarify, the nozzles are typically placed close where the dry material is deposited onto the spinner; the actual placement will vary according to systems, equipment, agency, and mechanic and operator preferences. As such, the term “just prior to the spinner” is more accurate than “at the spinner”.

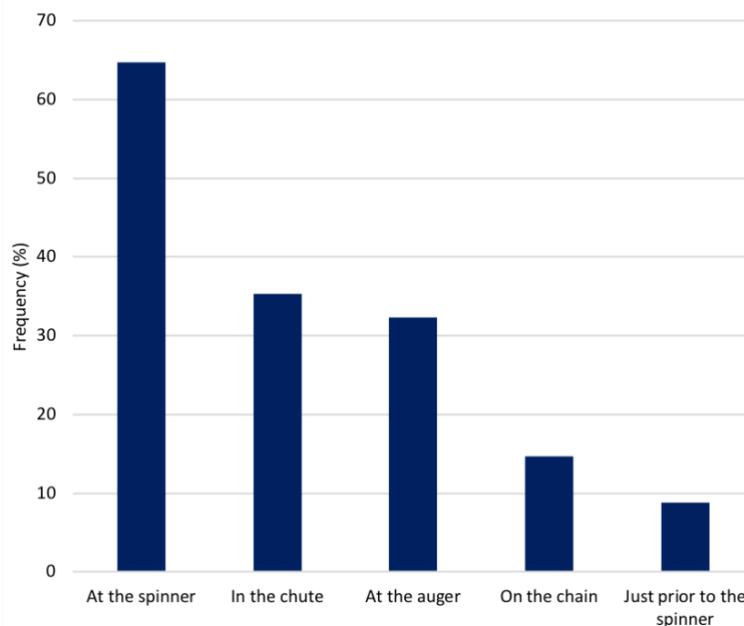


Figure 3.2. Frequency of different locations of the occurrence of pre-wetting mentioned by the survey respondents

When pre-wetting practice is used, the most common reported advantage over other WRM practices is that it can prevent bounce and scatter of the solid materials. Pre-wetting helps granular products stay on the roadway. Besides, for solid salt, a faster activation can be observed since pre-wetting can speed up the process of rock salt turning into a brine and jump-

start the ice melting process. For abrasives, pre-wetting helps it “burn” into the pack for higher friction coefficient. Another benefit of using pre-wetting mentioned by the respondents is the reduction of the amount of materials needed.

When asked to rank some factors in their agencies’ priorities to pre-wet, 29 survey respondents gave the following order from the most important to the least important:

- reduce material loss
- activate salt
- improve performance
- mitigate environmental impacts
- reduce corrosion
- reduce or control costs
- other

Specifically, pre-wetting allows for lower application rates than dry material application only, according to almost all the survey respondents. On average, an approximately 30% reduction in salt usage is found and documented by the agencies who track granular use. In other words, the application rate (lb. per lane-mile) of material is lowered by 30% when pre-wetting practice is used.

The most commonly mentioned pre-wetting rates (liquids to solids) range from 7 gallons per ton to 15 gallons per ton. For instance, the Oregon DOT has calibrated all the equipment to pre-wet at 15 gallons per ton for both salt and sand. For trucks equipped with pumps to make salt slurry, a higher pre-wetting rate can be achieved. In this case, the pre-wetting rate of 30–50 gallons per ton is usually used depending on granular size of solid material.

Of the total 33 responses, 19 respondents said that their agencies always used the current pre-wetting rate. Thirteen survey respondents mentioned that a lower pre-wetting rate was used earlier and now their agencies have switched to a higher rate. Only one agency lowered its pre-wetting rate. Those respondents who reported a higher pre-wetting rate than before adjusted their rates mainly because better operational results have been usually observed with higher rates. For example, at the pre-wetting rate of 10 gallons/ton, the salt is still pretty dry, while the salt pre-wetted at 20 gallons/ton is noticeably wetter and stickier. In this context, higher pre-wetting rates have proven to reduce the bounce-and-scatter of the salt and speed up the salt activation. The practitioners also reported that a higher rate has the ability to reduce the amount of granular salt needed, save money, and reduce chloride loading into the environment.

The majority of the survey respondents reported that their agency switched from electric pump to hydraulic pump so as to allow for the application of higher rates. Some DOTs (e.g., Oregon, Vermont and Massachusetts) prefer the use of hydraulic pumps over electric pumps, because they have been easier to calibrate (for better spreader control, especially when varying the pre-wetting rate¹) and/or less prone to corrosion issues (and thus require less maintenance or spreader down time). The Washington State DOT brings a quite different position, with the preference of electric pumps and successful user experience of approximately 10 years; relative to hydraulic pumps, these electric pumps provide more volume and are less expensive, easier to maintain, and easier to adjust². Some DOTs (e.g., North Dakota and Massachusetts) now use gravity feed system for pre-wetting, so that no pumping is needed and no more concern over the maintenance of pumps.

About half of the respondents reported that their agencies determine the pre-wetting rates based on the tank capacity (Figure 3.3) or the truck's capacity. Sometimes the pump capacity is also a limitation. The other half mentioned that the pre-wetting rate is based on many factors, such as road temperature, traffic volume, precipitation rate and type, cycle time, and other operation conditions. The tank capacity is usually not a limitation; sometimes the saddle tanks are even sized for the required pre-wetting rate. In other words, the pre-wetting rate is first determined by the research guidance and best practice, then the saddle tank capacity is determined by the liquid requirements.

¹ The Oregon DOT experience has been as follows. All of the electric pre-wet systems were controlled independently from the spreader controller, i.e., with their own controller; as such, the pre-wetting rate (by time) did not change with the actual material rate being applied. So if it's set at x gallons per hour, it just stays at that rate regardless whether the truck is going slow or fast. The hydraulic pumps apparently are ground speed controlled, which provides the ability to vary pre-wetting rate (by time) to stay a consistent 15 gallon/ton of salt applied.

² The Washington State DOT experience has been as follows. They are literally using 5 GPM pumps that are most often used in RV's to pump water. They are attached to the hydraulic controller through a rheostat that allows for variable volume to be supplied via the electrical pump. The rheostat is adjusted by the hydraulic controller when properly calibrated, as a result the pump motor turns at different rates to provide variable flow rates. The hydraulic controller monitors the cycles of the flight chain or auger along with the speed of the truck and provides the appropriate amount of material based on the set rate (operator's desired rate). The pump method, hydraulic or electrical, relies on the same type of hydraulic controller to accomplish variable rates. The DOT trucks have very complex hydraulic systems on them operating front plows, belly plows, spreaders etc.; if a lot of load is put on the system the hydraulic pump does not always deliver sufficient flow. This can be accounted for by increasing capacity but is significantly more expensive than simply using an electric pump.



Figure 3.3. Tank with 400 gallons capacity (courtesy of North Dakota DOT)

4. Equipment for on-board pre-wetting

Fewer survey respondents answered the questions in the equipment section. Only 27 survey respondents (from VT, WA, Ontario, MT, IA, OR, MI, ND, AZ, OH, KS, DE, MA, MI, ME, MN, AL, IL, WI, ID, PA, WV, and MD) answered the question about the wet liquid delivery system (pump size and type). 16 of them use hydraulic pumps while only 10 of them reported that electric pumps are used. Generally, old trucks are equipped with electric pumps, whose size is about 5–7 gallons per minute. Hydraulic-driven pumps with a 10-18 gallons per minute (GPM) capacity are usually used in newer trucks, such as those for slurry applications³.

To put these into an operational perspective, if an agency aims to apply a high rate of 500 lb. salt per lane mile (i.e., 2,000 lb. or 1 ton per mile of four-lane highway), and a pre-wetting rate of 16 gallons per ton, then a pre-wetting rate of 16 gallons per mile is needed. With a truck speed of 30 mph, this translates to a (liquid) pumping rate of 8 GPM.

For the spreader configurations, 24 out of 34 respondents provided feedback. The spreaders commonly used in their agencies include:

- front discharge with conveyor chain
- wheel track sprayer
- tailgate spreader
- v-box spreader with chain conveyor
- rear discharge spinner
- zero velocity spinner
- center discharge spinner with V-hopper

³ The Washington State DOT reported that their old hydraulic pumps were only able to achieve 10-12 gallons per minute at best.

- saddle tank gravity to spreader spinner

Twenty-five survey respondents reported information about the nozzle type in this survey. The most common used nozzle is the fan nozzle. The reason for choosing the fan nozzle is mainly that it can lead to a more uniform coverage. Many agencies also use stream nozzles, because they allow the liquids to be more focused on solids and thus are perceived as more effective. For pre-wetting, only 1–4 nozzles are needed for the solids on the chute or spinner.

Only seven respondents (from VT, MT, OR, MI, MA, MN, and IL) knew the screen size of the pre-wetting equipment with values ranging from 16 mesh to 80 mesh. Half of the 34 respondents knew the hose diameter. The most common used size for the hose is one-inch in diameter. A survey respondent from North Dakota DOT increased the hose diameter in the tailgate tank from $\frac{3}{4}$ " to 1" in order to regulate the flow, as shown in Figure 3.4.



Figure 3.4. The yellow hose with a diameter of 1"

Eighteen out of 28 respondents who answered the question about the reliability of pre-wetting equipment thought it is just as reliable or more reliable compared with other winter maintenance equipment. It should be noted that this is based on the regular maintenance and calibration. 7 respondents reported pre-wetting equipment is less reliable since there are issues with liquid delivery pumps. The others mentioned that the reliability of pre-wetting equipment depends on operators or circumstances.

5. Recent development

Twenty-nine out of 34 respondents took the survey about the change in methods, equipment, and materials during the past 10 years. The most common mentioned change is the increased use of liquid. As a result, the liquid application equipment has also changed, such as larger pre-wetting tanks, increased pump size, and increased flow rate. Most of the survey respondents

reported that their agencies use technologies such as RWIS, AVL or MDSS to aid in determining when and how to use pre-wetting.

Most respondents reported that pre-wetting can lower the total cost of WRM operations, including material, equipment, and labor. However, the majority of them have not conducted the cost-effectiveness analysis yet.

One thing the survey respondents learned during the pre-wetting operation is that pre-wetting on top of the chain or in the auger (Figure 3) works better than at the spinner to activate salt, although this can cause corrosion issues. In this way, it is easy for salt to achieve the saturation condition. Another issue is keeping pre-wetting equipment maintained, especially at the end of the season as well as calibrating at the beginning of season. For example, the nozzle tends to plug and should be cleaned regularly.



Figure 3.5. Auger trough with a pre-wetting delivery pipe (courtesy of North Dakota DOT)

Almost all the survey respondents reported that their agencies have not conducted laboratory tests or field trials to determine pre-wetting rates or the effectiveness of pre-wetted solid materials. However, some pre-wetting guidelines, such as FHWA, Clear Roads, DOT guidelines, are followed by agencies. About half of the respondents said their agencies are sticking to the existing guidelines and the other half mentioned that their agencies are increasing the application rate or switching the pre-wetting location from the spinner to the chain or auger.

Chapter 4. Interviews/Case studies of Pre-wetting

1. Introduction

As WRM operations have significantly improved in recent decades, the experiences of transportation agencies with pre-wetting practice have substantially evolved due to advances in chemical products, delivery equipment and systems, and better empirical knowledge of successful methods. For example, pre-wetting equipment can involve a variety of liquid delivery systems and spreader configurations (Appendix B). Some equipment systems rely on electric pumps and others use hydraulic pumps. Additional factors include nozzle selection, optimum pressure, screen size, hose diameter and flow meter design. New technologies (e.g., zero velocity spreaders, modified spinners, and other delivery mechanisms) facilitate precise and effective applications of both solid and liquid materials. Furthermore, the prevailing climate, topography, population, and traffic characteristics of individual jurisdictions influence the selection and application of pre-wetting practices.

Agencies have long dealt with the challenges of sharply reduced budgets, loss of experienced personnel, obsolete and worn vehicles and equipment, environmental regulation and mandates, occasional shortages of materials, additional workload due to growth and development, and omnipresent public scrutiny.

The objective of this task is to compile a summary of pre-wetting practices through interviews and case studies of selected agencies, including equipment, materials, methods, and application rates and identify the history of successes and failures that have contributed to the current practices. The following synthesis of nine case studies of city, county, and state transportation agencies summarize current knowledge, practices, and supporting evidence of pre-wetting methods and procedures and identify specific gaps that can be addressed in future field testing and experiments, thus enabling agencies to become more efficient and effective in their practices.

2. Case Studies

The nine agencies chosen for interviews were identified from survey responses, research reports, and recommendations from the project subcommittee. The interviews gathered information from these agencies in the areas of pre-wetting materials, equipment, and methods used in clearing roads during inclement weather and provide detailed examples of successful practices useful for agencies to adopt new practices or modify their existing practices. The case studies included city, county, and state agencies that use only solid salt as well as agencies that use salt/sand blends as solid materials. The 20-question interview (Appendix A) also included questions on a range of liquids, specifically salt brine as well as low-temperature liquids. Some agencies specifically choose CaCl_2 , MgCl_2 or blends with agricultural byproducts to improve the cold-temperature effectiveness of salt. The interviews also explored the reasons and length of time that agencies have been practicing their current methods. In

addition, agencies addressed their evolution of pre-wetting practices over the years, how the public and elected officials have reacted, and any plans for future changes in practices.

3. Agency Characteristics

The nine case studies represent six states, two city agencies, and one county agency: Idaho Transportation Department, Illinois McHenry County, Lexington, MA, Massachusetts DOT, Farmington Hills, Michigan, Montana DOT, North Dakota DOT, Oregon DOT, and Vermont DOT. Agencies that participated varied in area of jurisdiction, population, and miles and types of roadways maintained during snow and ice events (see Table B.1 and B.2).

As expected, states that were predominantly mountainous (Idaho and Montana), experienced snowfall much of the year, while most other agencies had first snowfalls in October - November and last snowfalls in April - May. The average annual snowfall ranged from as little as five inches in some areas to as much as 80-120 inches in the higher elevations of Montana and Idaho. Other agencies reported average annual snowfalls statewide from 34 to 60 inches. While three states do not track the number of snow and ice events requiring treatment, several agencies reported a range of 25 to 60 snow events per year and ice events requiring treatment much less, from 2 to 6 per year.

Agencies reported roadway miles divided into the following categories based on FHWA criteria: interstate, freeways/expressways, principal arterials, minor arterials, collector, and paved rural/urban.

4. Road Maintenance Materials Used

Agencies reported their standard practices for use of wet and dry materials on roadways during snow and ice events. While most reported using rock salt, sand, and a salt/sand mix as dry treatments, some reported that they reduced their use of salt on roadways in close proximity to water bodies and used mixed materials only in extreme weather events. For example, McHenry County (Illinois) uses only salt and treats it with Thawrox or Clearlane products.

Table 4.1. Dry materials used for winter road maintenance

Agency	Rock Salt	Sand	Salt/sand mix
Idaho Transportation Dept.	Used	Used	Used
Illinois, McHenry County	Used	Not used	Used
Lexington, MA	Used	Not used	Not used
Massachusetts DOT	Used	Used	Used
Farmington Hills, MI	Used	Not used	Used
Montana DOT	Used	Used	Used
North Dakota DOT	Used	Used	Used
Oregon DOT	Used	Used	Not used
Vermont DOT	Used	Used	Used

4.1 Pre-Wetting Practices

The majority of agencies (75%) use MgCl₂ as a preferred pre-wetting agent. Three of those who use MgCl₂ also use straight salt brine. Three agencies use straight salt brine, two of which mix their brine with other ingredients, such as Geomelt (which is a beet juice concentrate).

Michigan is the only case study state using CaCl₂. North Dakota reported: “we started with just salt brine, which tends to freeze at -6°F or so and (ended up) breaking the pump and valves. So we started to add the Geomelt which brought the liquid’s freezing temperature down (significantly); and we were not damaging our pumping equipment as much. Once we put it down on the road, we started to see some of the other benefits, such as it is stickier, lowers the working temperature.”

North Dakota and Vermont do not use corrosion inhibitors in their pre-wetting products. Idaho reported that they do not use an inhibitor in the straight salt brine, but the MgCl₂ is purchased with an inhibitor already added. Michigan is using an inhibitor as a pilot during the current season, as time allows.

Table 4.2. Wet materials used for winter road maintenance

Agency	CaCl ₂	MgCl ₂	Straight Salt Brine	Brine Mix	Inhibitors added
Idaho Transportation Dept.	Not used	Used	Used	Not used	Used
Illinois, McHenry County	Not used	Not used	Used	Not used	Used
Lexington, MA	Not used	Not used	Not used	Used brine/carbohydrate	Used
Massachusetts DOT	Not used	Used	Not used	Not used	Used
Farmington Hills, MI	Used	Used	Used	Used	Used
Montana DOT	Not used	used	Used	Not used	Used
North Dakota DOT	Not used	Not used	Used	Used	Not used
Oregon DOT	Not used	used	Not used	Not used	Used
Vermont DOT	Not used	used	Used	Not used	Not used

All agencies except Oregon reported mixing their own brine using the Henderson Brine Extreme, Brine Boss by VariTech Industries, or VanTech SB 600 brine makers. Idaho reported using a variety of brine manufacturers in nine different locations statewide. Montana used the VanTech before moving to the Henderson “as technology has advanced.” The brine storage capacity varied across states, as shown in Table 4.3.

Table 4.3. Brine storage capacity

Agency	Brine Storage Capacity
Idaho Transportation Dept.	About 1 million gallons
Illinois, McHenry County	150,000 gallons
Lexington, MA	12,000 gallons of both brine and carbohydrate
Massachusetts DOT	310,000 gallons
Farmington Hills, MI	3,000 brine, 12,000 Geomelt, 18,000 stored 32-38% calcium chloride
Montana DOT	Varies per production site; 30-120,000 gallons
North Dakota DOT	Close to 2 million gallons
Oregon DOT	0
Vermont DOT	810,000 gallons for reported district only

The methods that agencies used for pre-wetting roads included:

- 1) purchased already pre-wetted
- 2) pre-wet in stockpile
- 3) shower-spray at loading
- 4) on-board

No agency reported using method 1, although Vermont said it had considered using it, especially for densely populated areas, but that cost was an issue. Vermont, Montana, and Oregon use pre-wet in stockpile, and all other agencies use on-board. Idaho reported using both shower-spray at loading and on-board methods. Most agencies (6 of 9) reported that all spreader trucks in their fleet were equipped with on-board pre-wet capability. Massachusetts reported that all of their contracted spreaders are equipped, and stated: “How effective is stockpile pre-wetting, or shower-spray at loading vs. on-board pre-wetting? Many of our own spreaders lack pre-wetting capability (and) we are trying to address this as an agency.”

The pre-wetting application rates for various road classifications (interstates/freeways, major surface arterials, minor arterials, collectors, and low volume roads/streets) is fairly consistent among agencies while allowing for variations per storm and conditions of the road surfaces. Four agencies use pre-wetting for every winter event while five say it depends upon the individual event. All states say their reasons for pre-wetting are: 1) reduces material usage, 2) faster deicing action, and 3) reduces environmental impact, (Idaho did not report reducing environmental impact as a reason for pre-wetting).

All case study agencies have been practicing pre-wetting for more than 10 years, and several for more than 30 years. Their reasons for long-term use are to increase efficiency and effectiveness, reduce bounce and scatter, activate salt crystals to create brine, reduce environmental impacts, and save on material.

Before implementing pre-wetting practices, some agencies conducted tests and trials and have continued those tests through multiple years. For example, Illinois conducted a bounce-and-scatter test on a remote roadway that had boxes painted on the surface; Idaho conducted many tests throughout the years. Some respondents did not know if there had been tests and trials performed as they were not with the agency at the time pre-wetting practices began. However, agencies utilized various information sources about pre-wetting, as listed in Table 4.4.

Table 4.4. Agencies utilization of information sources

Agency	Clear Roads Project Reports	Vendors/manufacturers	Discussions with Peers	APWA	AASHTO	TRB	NCHRP	PIARC
Idaho Transportation Dept.	X				X	X	X	
Illinois, McHenry County	X	X	X	X	X	X	X	X
Lexington, MA*	X	X	X		X			
Massachusetts DOT	X	X	X					
Farmington Hills, MI	X			X	X	X		X
Montana DOT	X	X	X					
North Dakota DOT	X	X	X	X	X	X	X	X
Oregon DOT	X		X				X	
Vermont DOT	X	X	X					

*Other: LTAP seminars

4.2 Pre-wetting Practices Changes

All responding agencies have changed their pre-wetting practices since first implementation based on increased understanding, support, and better equipment and technologies. Additionally, the agencies have increased capacity, better training, and positive community backing. For example, a quote from the North Dakota agency says: “More acceptance since it’s started. More compliance, more capability (equipment and knowledge), increased capacity. We started slow but then once people see the value and they want to do it more and seek out more equipment and capabilities. Building on that, they run out of capacity; then get more equipment; a snowball effect in a positive way.” Other agencies also reiterated the snowball effect of starting with experimental to optional operations to mandatory over the years that

included an evolution of understanding of the positive outcomes of pre-wetting practices. For the most part, these changes have been gradual, starting the practice in small areas and eventually expanding statewide. Most agencies have also upgraded equipment to include larger capacity, bigger volume and hydraulic pumps, spray nozzles, ground speed sensors, and live bottom v-boxes.

Agencies reported some initial resistance from operations staff for pre-wetting, but once the positive results became apparent, de-icing became more efficient, and comfort level increased, staff became supportive. Additional training and information were required in most agencies to gain acceptance from staff, accomplished by some during internal meetings and annual maintenance conferences.

Initial resistance from higher-level and elected officials was also present in most agencies because of concerns about the corrosive effects of deicing chemicals to equipment and infrastructure and the environmental issues, particularly in Vermont and Montana. Providing information where resistance and skepticism exist has helped alleviate the problem. In addition to resistance from higher level officials, other obstacles and impediments existed for agencies transitioning to pre-wetting such as cost, equipment, capacity, logistics of producing, and workers. Massachusetts noted some negative opinions based on an earlier misapplication of $MgCl_2$ on warm roadways, and Michigan stated that overspray on windshields hindered driver visibility.

Massachusetts and North Dakota said that the public was not aware of their pre-wetting methods; however, other agencies reported that the public reaction is favorable and positive. Montana said that its public is still concerned about corrosion and the environment. Only one state, Vermont, however, publicized its use of pre-wet materials on roads. Massachusetts, Idaho, Montana, Oregon, and Michigan said they do not inform the public and media of the use of pre-wetting. North Dakota sends out flyers, and McHenry County Illinois is starting to use social media, while Idaho “talked generally” about the use of liquids.

Agencies provided their level of service (LOS) policies for this project, reporting that, though their levels of services have not changed since they first implemented pre-wetting practices, pre-wetting usually allows them to obtain their LOS quicker (as reported by Montana). Vermont did increase its LOS but reported that it was not due to the use of pre-wetting practices.

All responding agencies recorded a positive evaluation/assessment of their pre-wetting practices. Reasons include:

- better salt performance
- increased LOS provided
- improved performance of materials used
- abrasives last longer

- less material used
- faster start to the melting process

Some agencies are considering changes to their pre-wetting practices, such as purchasing pre-treated salt, slurry application, and a reliable management system in vehicles. Illinois stated that it is always open and looking for ideas, particularly products that are friendly to the environment.

5. Equipment

Pre-wetting equipment case studies included agencies with both advanced and minimal technological tools. Agencies frequently have multiple generations or versions of equipment as replacements are usually phased and manufacturers routinely introduce new or modified versions. This was evident in the nine case studies for this project. The use of after-market pre-wet systems and spreaders with integrated pre-wet systems were both included. For those agencies not using telematics, all indicated that they planned to in the future. Table 4.5 summarizes the main questions regarding equipment, maintenance, speed, and the use of telematics. Additional information regarding equipment, such as type, make, and model as well as maintenance are detailed in Appendix B.

Table 4.5. Equipment, maintenance, speed, and use of telematics

Agency	# Spreader trucks with on-board pre-wet capability	Make and Model of on-board pre-wet equipment	Maintenance and Calibration	Spreader ground speed	Use telematics?
Idaho Transportation Dept.	442	Certified/Cirus Spreadsmart RX Controllers	Flushing and screen cleaning as required	25-35. May go faster on interstates	AVL on 100% of fleet
Illinois, McHenry County	31	Force 6100 and Force 5100	Early season constant screen cleaning and flushing system at end of season	20-30 mph depending on environment	Not at this time, but on-board computers monitor application rates
Lexington, MA	9	Schmidt, VariTech	Twice per season	30 mph; not over 20 mph in town	Implementing this season
Massachusetts DOT	1,536	Hi-Way spreaders, Cirus Spreadsmart controllers	Screen cleaning and flushing	25-30 mph	Yes
Farmington Hills, MI	17	Rexroth Systems, Storm Guard Systems	Cleaning screens and calibration every fall	10-20 mph, but no limit enforced	AVL system Skyhawk monitors pavement temp
Montana DOT	625	Force America SSC 1500, 5100;	Flushing tanks, cleaning screens	25-35 mph	Some monitor rates and

		Ravens 710; Cirus Spreadsmart	and nozzles, pump, flow meter		distances applied
North Dakota DOT	350	Force American controllers	Storage tanks with Geomelt cleaned	30 mph	No, but testing with AVL units
Oregon DOT	135	Varies	Calibrated once per year	Training provided	No, but will in the future
Vermont DOT	247	Viking Proline, Certified Power controllers	Screen cleaning and flushing	25 mph on all routes; 30-35 interstates	Yes

6. Conclusions

Out of the nine case study agencies, most reported using rock salt, sand, and a salt/sand mix as dry treatments, some reported that they reduced their use of salt on roadways close to water bodies and used mixed materials only in extreme weather events. Most agencies (75%) use MgCl₂ as a preferred pre-wetting agent. Three of those who use MgCl₂ also use straight salt brine. Three agencies use straight salt brine, two of which mix their brine with other ingredients, such as Geomelt, which is a beet juice concentrate. Michigan is the only state using CaCl₂.

All agencies, except Oregon, reported mixing their own brine using variety of brine manufacturing equipment. The brine storage capacity varied across states.

The methods that agencies used for pre-wetting solids included: 1) pre-wet in stockpile, 2) shower-spray at loading, and 3) on-board. Most agencies reported that all their spreader trucks were equipped with on-board pre-wet capability.

Pre-wetted material application rates for various road classifications (interstates/freeways, major surface arterials, minor arterials, collectors, and low volume roads/streets) is fairly consistent among agencies while allowing for variations per storm and conditions of the road surfaces. Four agencies use pre-wetting for every winter event while five say it depends upon the individual event.

All respondents have been practicing pre-wetting for more than 10 years, and several for more than 30 years. Their reasons for long-term use are to increase efficiency and effectiveness, reduce bounce and scatter, activate salt crystals to create brine, reduce environmental impacts, and save on material.

Before implementing pre-wetting practices, some agencies conducted tests and trials and have continued those tests through multiple years. All responding agencies changed their pre-wetting practices since first implementation based on increased understanding, support, and better equipment and technologies. Additionally, they have increased capacity, better training,

and positive community backing. For the most part, these changes have been gradual, starting the practice in small areas and eventually expanding statewide. Most agencies have also upgraded equipment to include larger capacity, bigger volume and hydraulic pumps, spray nozzles, ground speed sensors, and live bottom v-boxes.

Agencies reported some initial resistance to pre-wetting from operations staff, but once the positive results became apparent, de-icing became more efficient, and comfort level increased, staff became supportive. Additional training and information were required in most agencies to gain acceptance from staff. Initial resistance from higher-level and elected officials was also present in most agencies because of concerns about the corrosive effects of deicing chemicals to equipment and infrastructure and the environmental issues. Providing information helped alleviate the opposition. Other obstacles and impediments for agencies transitioning to pre-wetting include cost, equipment, capacity, logistics of producing, and worker availability.

Though levels of services (LOS) have not changed since they first implemented pre-wetting practices, pre-wetting usually allows them to obtain LOS quicker. All respondents recorded a positive evaluation/assessment of their pre-wetting practices, such as better salt performance, improved longevity of abrasives, less material used, and faster start to the ice melting process.

Some agencies are considering changes to their pre-wetting practices, such as purchasing pre-treated salt, slurry application, and a reliable application management system in vehicles.

Case studies included agencies with both advanced and minimal technological tools. Agencies frequently have multiple generations or versions of equipment as older trucks are incrementally replaced. Typically, replacement schedules can range from 7-20 years or longer.

Chapter 5. Outreach to Equipment Manufacturers/Distributors

1. Introduction

Winter road maintenance (WRM) operations methods, technologies, and products have significantly improved over the last two decades, creating a need to synthesize relevant best practices and equipment for pre-wetting salt, sand and other dry materials. Pre-wetting has evolved from applying liquids to stockpiled materials or by spraying onto dry materials after loaded onto trucks. Now, State (DOT) and local (DPW) transportation agencies must consider a wide range of advanced on-board pre-wetting systems and spreader configurations consisting of electric or hydraulic pumps, nozzle selection, optimum pressure, screen size, hose diameter and flow meter design. Additionally, zero velocity spreaders, modified spinners, controllers and other delivery mechanisms facilitate precise and effective applications of both solid and liquid materials. These factors necessitate an updated, comprehensive review of the methodologies and application rates currently used for pre-wetting operation.

All transportation agencies in recent years have faced the challenges of sharply reduced budgets, loss of experienced personnel, obsolete vehicles and equipment, environmental regulation and mandates, occasional shortages of materials, additional workload due to growth and development, omnipresent public scrutiny, and higher expectations. Pre-wetting has proven to be a more effective and efficient technique for roadway snow and ice control, yet many agencies have either not upgraded their existing equipment and application procedures or have not fully adopted this method. The following synthesis of pre-wetting equipment, products and capabilities is intended to assist DOTs/ DPWs in determining the critical composition, configuration and selection of pre-wetting systems for their particular needs.

For this project, six manufacturers/distributors were interviewed or surveyed including Henderson, SnowEx, Epoke (reported by distributor Wausau Equipment Co.), Hilltip Corp., Monroe Truck Equipment, and New Leader Manufacturing (which manufactures Hi-Way brand equipment). Douglas Dynamics, Inc. is a manufacturer and upfitter for snow removal truck attachments and equipment with brand-name-products Henderson, SnowEx, and Western. Hilltip Corp manufactures its products in Finland and has several dealers in the U.S.

Unfortunately, several other manufacturers did not respond to repeated requests to participate in this project. The locations and contact names for each respondent in this study are located in Appendix D.

2. Equipment Capabilities

Pre-wet equipment capabilities were identified through questionnaires sent to manufacturers and vendors. In addition to information about equipment specifications, the researchers asked questions about manufacturer's instructions and guides for installation, operation, and

maintenance. Information about any research or tests that were conducted were identified, and manufacturers provided manuals and training options as supporting documentation.

Some manufacturers sell pre-wetting systems to be added to in-use spreaders and some sell spreaders integrated with pre-wetting abilities. Each were included to cover the range of options available for DOTs/ DPWs looking to incorporate pre-wetting. Figure 5.1 provides some examples of pre-wetting equipment provided by manufacturers/distributors.

Epoke North America, Inc:
www.epokena.com/products/



Epoke S4900/4902 Sirius AST Combi

Henderson Products, Inc:
www.hendersonproducts.com



Henderson Products – Illinois turnkey package

Snow Ex: www.snowexproducts.com/products/spreaders



Snow Ex Super Maxx II 6 cubic yard spreader with integrated pre-wet system

Western Products:
www.westernplows.com/products/pre-wet-system



Western Striker Pre-Wet Hopper System

Figure 5.1 Examples of pre-wet equipment available from several manufacturers.

The questionnaire used to gather data is attached as Appendix C. The specific questions were provided to the project subcommittee for review and approval before interviews were conducted. Interviews were performed through a combination of phone calls and emails. The research team originally intended to conduct the interviews and equipment inspections at various winter maintenance conferences that they attend , but all were cancelled in 2020 (and so far in 2021) due to the COVID-19 pandemic.

3. On-Board Systems

Manufacturers were asked seven questions about the on-board systems they build or distribute. Table 1 specifies the different sized trucks and trailers that their on-board systems fit.

Table 5.1. Q A1 (a-g) and QA2. How many of the following different sized trucks do you build equipment for, and Q 2. Can specification sheets be obtained for each different system? If possible, include photos and drawings.

Manufacturer / Vendor	½ ton pickup	¾ ton pickup	1-ton utility truck	Single axle dump or flat/stake bed	Tandem axle dump	Other	Trailer	Spec. sheets available ?
Henderson Products			x	X	x	Tri-axle dump		Varies
Snow Express	x	x		X		UTV		Yes
Hilltip Corp	x	x	x	X		UTV/tractors/skid steers/tool carriers	x	Yes
Epoke			x	X	x	Tri-axle dump	x	Custom chassis
Monroe Truck Equipment, Inc.	x	x	x	X	x		x	Yes
New Leader Manufacturing		x	x	X	x	Tri-axle dump		Yes

For questions A3-A6 of the questionnaire, manufacturers reported the liquid tank capacity and location, the granular hopper capacity, power, and GPM rating of the tanks. Some manufacturers, such as Henderson, builds many sizes of tanks with varying capacities, so the options can be suited to fit the needs of any agency.

Manufacturers build their tanks to fit securely on specific vehicle body types. Some systems are integral to the unit, while others are designed to mount on the sides of the unit, on the tailgate, inside the dump body, externally to the dump body, to the body platform fenders, mounted with brackets to the outside of the dump body sides, or slid into the back of a traditional dump body. Figure 2 provides an example of one type of tank mount.

Table 5.2. Q. A3-7. Tank capacity and location for each system, pump power, and GPM rating

Manufacturer/ Vendor	Liquid Tank Capacity	Tank location	Granular hopper capacity	Utilized power to pump	GPM rating
Henderson Products	Henderson Products builds eight different styles of tanks and each style comes in multiple sizes. The smallest		The capacity of the granular tanks were reported in cubic yards. Again, each system is built in	all systems that feature a basic prewet system only where liquid application is distributed at	Prewet system (Hydraulic): 4.1 Prewet System w/Slurry (Hydraulic): 8.2 Prewet System w/Slurry

	capacity tank holds 75 gallons, while the largest, the LAS, holds 1800 gallons. Some equipment is built for dual capacity, essentially doubling the amount of liquid capability. For example, the Blackbelt Maxx comes as 11-17 foot dual tanks with each tank holding 155 – 320 gallons each. These dual tanks are mounted on the sides of the vehicle’s body unit. The location of the tank placement for each product is discussed in the next section.		a variety of lengths and sizes, thus the capacity variations for each manufacturer numbered, for some, close to 100. The smallest granular capacity tank was 4.5 cubic yards while the largest reported was 26.4 cubic yards.	the spinner chute to pre-wet granular material prior to spreader are either run by a 12v liquid pump or a hydraulically driven pump which is powered by the trucks central hydraulic system. Systems that feature a slurry option and/or anti-ice spray system are hydraulically driven, driven a hydraulic pump, powered by the trucks central hydraulic system	(Hydraulic): 3.0 Anti-ice System (Hydraulic): 190
Snow Express	SnowEx Tank capacity is 100 gallons for the 2.0yd and smaller capacities. It is comprised of (4) 25-gallon tanks. Tank capacity is 200 gallons for the larger models, with an optional 100-gallon system that can be added for a total of 300 gallons. It is comprised of (4) or (6) 50-gallon tanks.	Tank has been designed to fit in between the legs of the hopper as show in the photo below	SnowEx models that have pre-wet capability: HELIXX Poly: 1.5yd, 2.25yd, 3.5yd & 5.0yd HELIXX Stainless Steel: 0.7yd, 1.5yd, 2.0yd, 3.0yd, 4.5yd & 6.0yd	systems are wired the same and power is supplied from the vehicle battery through a fused harness kit.	7GPM pump to feed the unique “Triple Threat” capability in which it can spreads solids, pre-wet the solids or DLA (Direct Liquid Application).
Monroe Truck Equipment	30-1300 gallons prewet pending body size; 225-6500 gallons direct liquid application	Chassis frame, dump body tailgate, slip-in dump body or mounted on v-hopper dander	2 – 15 cu yds	Most systems are hydraulic powered but electric is also available	1-6 gpm electric driven prewetting; 1-10 gpm hydraulic driven pumps prewetting; 75-

Hilltip Corp.	Varies based on size of spreader/sprayer. 87-550 gallons	All are built into the hopper of the spreader in the same place mounted to a frame that is mounted to the truck	Varies; our smallest unit holds 4.5 ft.Â³ of solid material and our largest machine handles 6.0 yd.Â³.	Electric motors	210 gpm direct liquid application 7 gpm per pump. If users opt for a pre-kit and spraybar, machines are fitted with 2 pumps
Epoke	500-1765 gallons	Typically placed on the truck behind the cab with weight distributed equally over chassis. This is done by using saddle tanks and tanks in front of the solid material hopper	Various hopper sizes are available from 4 cu yds to 12 cu yds	There are various ways to provide required hydraulic power to the pump(s) including chassis hydraulic system (PTO), drive wheel and independent diesel engine	Max GPM of liquid is 78
New Leader Manufacturing	Tailgate spreader system – 100-gallon single tank Vee Box Spreader System / standard – 75-gallon single or dual tank system, 100-gallon single or dual tank system. Vee Box Spreader System / Slurry Machine – 232-gallon each dual system (464-gallon total), 300-gallon each dual tank system (600-gallon total), 362-gallon each dual tank system (724-gallon total) and one 400-gallon vee box insert tank for the slurry system that works in	On a tailgate spreader the tank is mounted on the dump body tailgate On a vee box spreader, the tanks are mounted on the side of the body. On a multi-purpose body, the tanks are mounted; 1) on the body fenders or, 2) on a subframe located under the multi-purpose body or, 3) inside of the body (reduces granular	On a tailgate spreader system, the granular capacity is dependent upon the size of the dump body. On a vee box spreader, the granular capacity is again dependent upon the size of the body. Our vee boxes have capacities (struck) starting at 5 cubic yards and going to as much as 12 cubic yard capacity. On slurry style units the higher capacity of the	Pre-wet systems offered can be powered by either 12-volt electric or by the truck’s central hydraulic system	On a standard style pre-wet system, the pump output is 3.3 – 10 GPM. On a slurry type machine the pump output is 15 – 25 GPM

conjunction with the 724-gallon system to provide 1100 gallon of liquid. Multi-purpose body systems – 65-gallon fender mounted tank (can be mounted on one or both fenders), 95-gallon fender mounted tank (can be mounted on one or both fenders), 200-gallon and 300-gallon sub-frame mounted systems and 900-gallon to 1400-gallon body insert systems.

capacity).

liquid reduces the granular capacity to the range of 5 cubic yards to 8 cubic yards (struck) capacity. On multi-purpose bodies, the granular capacity with fender mounted tanks or sub-frame mounted tanks the granular capacity ranges from 8 cubic yard to 17 cubic yard depending upon the length of the body. With the insert tanks the granular capacity is cut by about 40%



Figure 5.2. SnowEx tanks have been designed to fit in between the legs of the hopper as show in the photo above.

Question B: Optional Equipment

Manufacturers were asked if any option equipment, such as pumps or controllers, are available for each system and if so, to elaborate. Henderson customizes all its systems to meet the needs

of the customer with options too numerous to list. Most systems beyond basic pre-wetting are going to use some type of advanced control system. These control systems are available through numerous control system manufacturers including but not limited to: Force America, Certified Power, Muncie Power, Dickey John, and many others. The offering available through these organization is vast. Hilltip offers 2-way GPRS tracking systems, prewet kits, spray bars, hose reels, strobes, lights, bladders, leg stands, extended chutes, and more.

SnowEx hoppers, as previously specified, have optional pre-wetting accessory kits. The accessory kit comes with everything needed for installation and operation that isn't standard equipment for the base model hopper. The standard control is capable of operating the accessory once installed. There are 4 buttons across the top that are utilized for accessories, as seen in Figure 3 below. When the pre-wet kit is installed, one of those buttons will light up and is back lit showing "pre-wet" as its designated functionality.

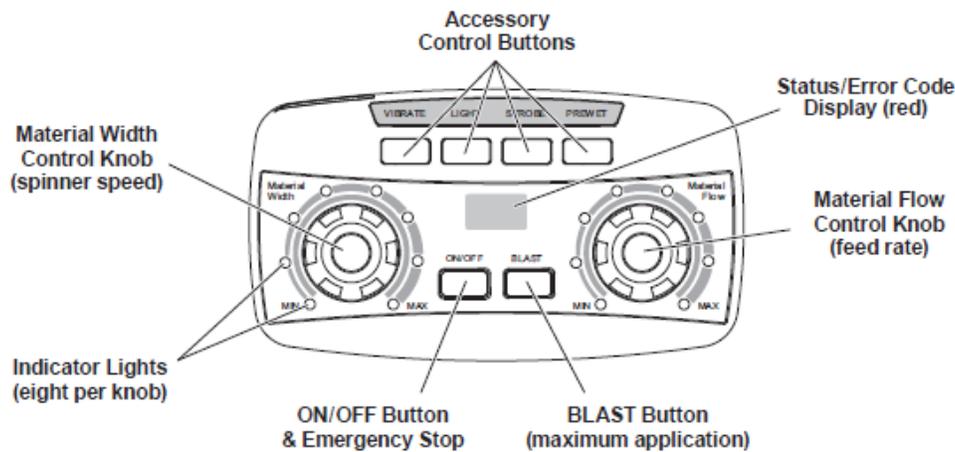


Figure 5.3. SnowEx hopper accessory kit

Monroe reported that its optional equipment includes open loop systems; Monroe supplies a simple controller; closed loop controls would be supplied by Force America, Certified Power, Dickey John, Rexroth, Parker, Cirrus etc.

New Leader Manufacturing reported that, while a pre-wet system can be purchased from them with a control for the system, it is typical for the control of the system to be "within" the control system for the hydraulic package of the truck. This is the system that controls the plow functions, spreader functions, pre-wet functions and if so equipped, anti-icing functions. It is rare, other than retrofitting an older truck, to have a control only for the pre-wet system. As far as optional attachments to the various systems, New Leader does not offer any.

Question C: Calibration

Manufacturers were asked to report their methods of information and/or training on how to calibrate equipment.

Table 5.3. Question C1-C3C: Calibration, required equipment, and skillset for changing calibration

Manufacturer/ Vendor	Do you provide training on how to calibrate?	What equipment is required and who do you recommend perform	Once calibrated, how easy for driver to change?
Henderson	Training on system calibration is often provided by the salesperson who sold a unit and oftentimes by the hydraulic/control system provider. Basic prewet system that just wets using granular material as it enters the chute can be controlled by a basic control head or a full control system. The basic control head uses a rheostat setting which outputs material based on dial setting. This info can be found in the user guide. Full control type systems require additional data sets when setting up and calibrating. Instructions are provided with each kit.	Certain systems are equipped with flow meters where the K-factor (flow meter sensor calculates speed, flow, etc.) is entered into the control system console. In addition, information such as gallons per lane mile desired are inputted into the control system. Generally, a DOT or municipality has a pre-determined gallons per lane mile they wish to achieve. Many of today's control system monitor truck speed and based on the desired gallons per lane mile and K-factor feedback, the control console will adjust liquid output.	Many control systems have an operator mode and an administrative mode. Many municipalities will have the system set to operator mode which provides the driver with limited access in adjusting certain rate. The ability for the driver to change calibration settings depends on the system or access rights, or programming key.
SnowEx Epoke	Not reported Yes, formal training on calibration is provided at time of delivery. Detailed calibration procedure is also documented in instruction/operations manuals	Not reported No specialized tools required. Items required: Scale, heavy-duty plastic bag. Calibration can be done by anyone assigned the responsibility both mechanics and operators	Not reported Calibration is password protected in the program. No one can change calibration unless they have a password.
Hilltip Corp	Yes, information is available on calibration on the controller itself and through training with factory representation	No specific equipment is required	Moderately difficult. The driver would have to know the procedure to get into the calibration screens on the controller and have the authority to override it.
Monroe Trucking Equipment	Yes, in-house training or on-site training for Force America Controls. Other brands of controllers rely	Weight scale, catch tubs, graduated gallon container	Calibration is typically only changed by management

New Leader	on their factory sales staff. Yes, provided in the operation manuals	To calibrate a product is normally pretty easy using a stopwatch, some hand tools, a 5-gallon bucket and a scale	Depends upon who owns the product. Some agencies require a password to modify the program.
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Application

Question D asked manufacturers to report on application rates for each system. All respondents reported both solid and liquid output for their systems using gallons per lane mile, pounds per lane mile, or pounds per minute based on weight of materials. Monroe tracks pounds per lane mile for solids and gallons per ton of granular products. SnowEx provided a manual of its HELIXX brand system that included the following table for application rates.

OPERATING INSTRUCTIONS

APPLICATION RATES

The following application chart shows the approximate material delivery rate for HELIXX™ hopper spreaders. Use these charts to determine the auger delivery rate of de-icing salt, which is based on the auger speed.

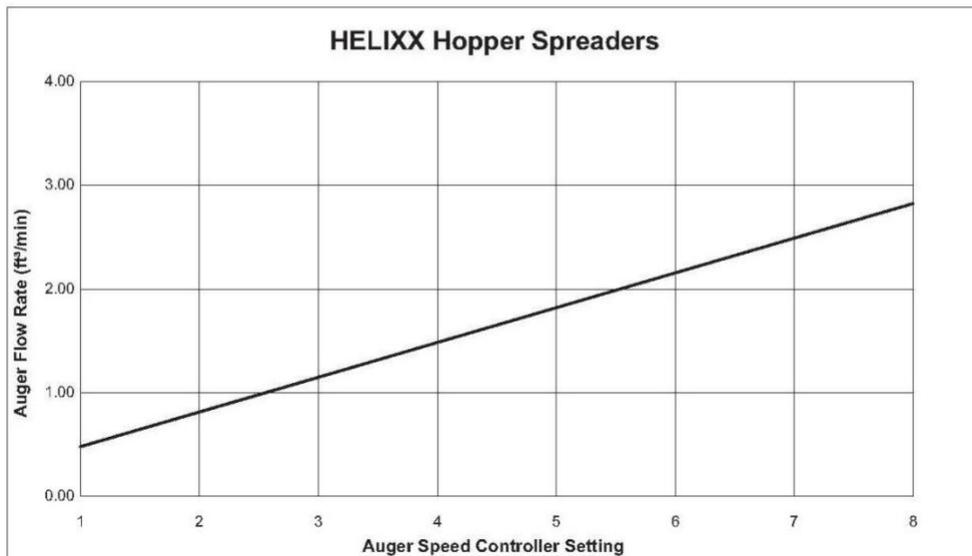


Figure 5.4. HELIXX hopper spreader application rates as provided by SnowEx.

Table 5.4. Range of Applications for each system

Manufacturer/ Vendor	Range of Applications
Henderson	Application output in the snow and ice industry are generally described using lbs./lane mile for granular or gallons/lane mile for anti-icing. Example Application Rates Anti-icing (brine or brine blend @ 30-40 gallons per lane mile) Salt application 100-300 pounds per lane mile
SnowEx	Included range of applications in its operating instructions and is shown in Figure 4.
Hilltip Corp	335 lbs./min; 12.25 lbs./1000 ft A ² ; 850 lbs./lane mile. The pumps run at 7 gpm.
Epoke	Solid weights vary based on material weight. 0 to 992 lbs. per minute max (sand) Liquids will also vary based on weight of material 0-78 GPM
Monroe	Solids are typically called out in pounds per lane mile and liquid is called out in gallons per ton of granular product. Granular product can range from 100-2000 pounds per lane mile pending 100% salt, salt/sand mix, 100% sand. Liquid will typically be from 10 – 75 gallons per ton of granular.
New Leader	Granular low end = 65 lbs./min

Question E: Documentation

Question E asked respondents to report on tracking capabilities, as shown in Table 5. Most reported having advanced systems for data recording capabilities through the use of plow cams, GPS, and ground surface temperature thermometers. Many systems can monitor routes and track material distributed. These advanced technologies allow for the ability to gather data and adjust application rates as needed.

Table 5.5. Are applications tracked by the controller? Data types: GPS/AVL, rate of solids, rate of liquids, surface temperature, air temperature, camera?

Manufacturer/ Vendor	Can application rates be tracked by the controller?
Henderson	As snow and ice control systems become more advanced, usage of data logging features is becoming more prevalent. These include GPS/AVL, material discharge with GPS location, air temperature, ground surface temp as well as camera operation. DOT's such as IOWA Department of Transportation have Plow Cams on many of their winter trucks. These systems are most often provided by a hydraulic control supplier or third party.
SnowEx	No
Hilltip Corp	Yes, only Hilltip offers a 2-way GPRS tracking system allowing users to remotely change application and spinner rates from any device in the world. Our system also allows detailed reporting of all spreading metrics and geo-fencing capability for worksites to allow specific application rates per worksite, which helps to limit the impact of salt/brine on the environment.
Epoke	Yes, Epoke has the ability to collect data, monitor routes, surface and air temperature, material distributed, etc. through EpoTrack, EpoSat, EpoData and EpoTherm
Monroe	Many controllers do have data recording capabilities. All pending make/model
New Leader Manufacturing	If set with the proper control system, the applications can be tracked

Question F: Controller

Detailed controller information was asked, including the standard abilities, optional abilities, and if there is an operator's manual available for each system. Henderson and Monroe use numerous control system manufacturers for their equipment, while Epoke listed its own manufactured controllers. Two manufacturers reported using a Force America brand controller, as shown in Figure 5. This controller is the most advanced system offered by Force America. Table 6 details the controller information for each manufacturer/distributor.



Figure 5.5. Force America brand SSC6100 control system with a 10" color LCD and camera integration, cellular, and GPS technologies. Obtained from ForceAmerica.com/products.

Table 5.6. What is the standard controller with each system? What abilities does it possess? What optional controllers are available? What abilities does it possess? Can an operator’s manual be obtained for each controller?

Manufacturer/ Vendor	Standard controller and abilities	Optional controllers and abilities	Operator’s manual available
Henderson	Most systems beyond basic prewet are going to use some type of advanced control system. These control systems are available through numerous control system manufacturers including but not limited to: Force America, Certified Power, Muncie Power, Dickey John, and many others.		Yes. For operator manuals, we may need to reach out to these organizations for samples of their various control systems.
SnowEx Hilltip Corp	Not reported All Hilltip spreaders, with the exception of our tailgate units, come with our StrikeSmart controller. These controllers are equipped with ground control and manual operating modes allowing the spreader to start and stop with the vehicle. All optional equipment wired through the spreader can be controlled here as well. Any worksite created in HTrack is also visible on the controller	Not reported Hilltop offers no optional controllers. Our small spreaders utilize a smart phone we provide with our Strikesmart control app preloaded so the user can control the machine via a Bluetooth link. All functions of Strikesmart controllers are available in the Strikesmart app.	Yes Yes, conditionally
Epoke	Full control, adjustment and monitoring of material spreader is accomplished using the EpoMaster X-1 controller. Available both in a hardwired and wireless version Options available include EpoSAT, EpoTrack and Data Collection	Available in an EpoMini X-1 controller.	Yes
Monroe	Varies by customer. Certified Power, Force America, Cirus and Rexroth are primary suppliers. Major of controllers are ground speed oriented with data	Monroe does not manufacture controllers; we rely on suppliers mentioned	Many available on suppliers’ websites

New Leader Manufacturing	recording capabilities Plow-all functions; spreader-granular; spreader-liquid; dump body-up, down, tailgate hitch; data logging	Tow plow operation, road temperature sensors, de- icing function, cell or wi-fi	Manuals would come from suppliers, including Bosh Rexroth, Certified Power/Cirus Controls, Force America, and Muncie Hydraulics
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Feed Mechanism (solids)

SnowEx reported using the patented HELIXX shaftless auger system and included the manual for the system with their questionnaire. Henderson’s feed mechanisms included a variety of different systems including pintle chain, roller chain, belt over chain, single auger, and dual auger as well as STD & SS. Epoke reported using the “Epoke principle” in their spreader, which includes an agitator to break down the material supplied to the delivery roller, as shown in Figure 6. Detailed answers are included in Table 7.

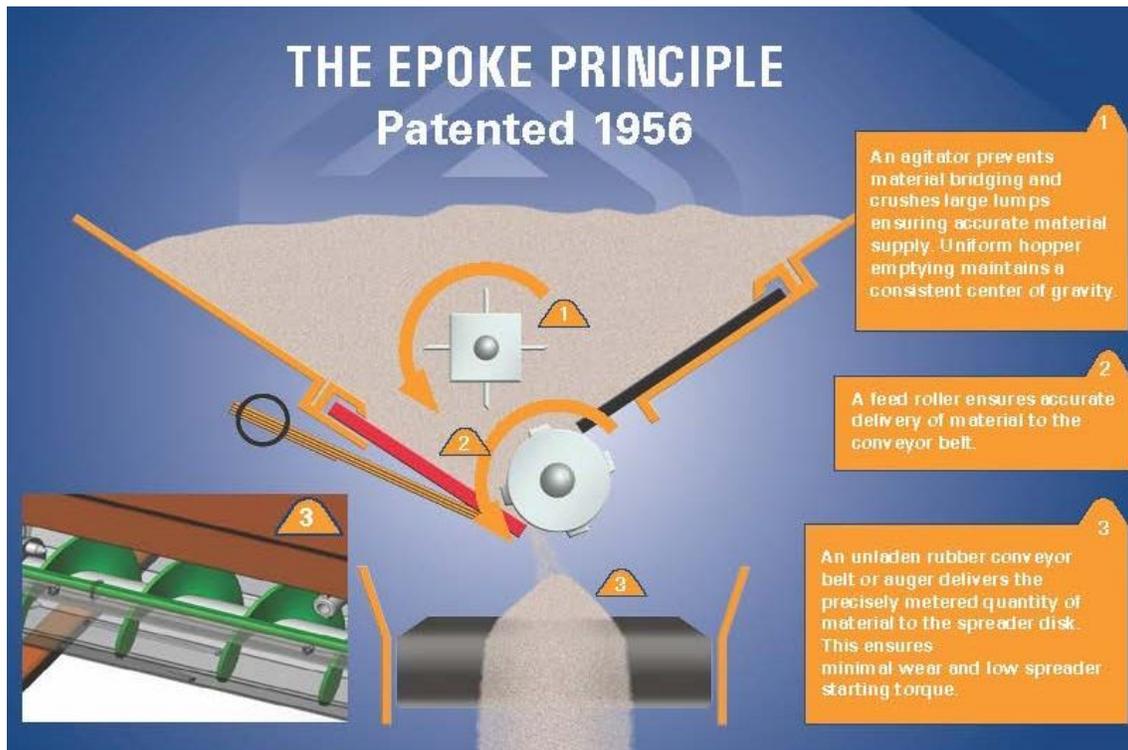


Figure 5.6. A visual representation of the Epoke patented system feed mechanism.

Table 5.7. Manufacturers were asked to record the feed mechanisms on their equipment that moves the solid material.

Manufacturer/ Vendor	Feed Mechanism
Henderson	FHS: Std & SS Pintle Chain, Roller Chain, Belt Over Chain, Single Auger, Dual Auger Task Force: Std & SS Pintle Chain, Roller Chain, Belt Over Chain, Single Auger, Dual Auger Munibody: Std & SS Pintle Chain, Roller Chain, Belt Over Chain, Single Auger, Dual Auger First Response: Dual auger BlackBelt Maxx: Pure belt
SnowEx	Patented HELIXX shaftless auger system
Hilltip Corp	Your choice of auger, chain, or conveyor belt
Epoke	Epoke material spreaders use the “Epoke Principle” which includes an agitator in the hopper to help break down the material being supplied to the delivery roller. The delivery roller then meters the material allowing it to move to the conveyor or auger and ultimately to the spinner for distribution to the surface being treated.
Monroe	Pintle style drag chain or auger
New Leader Manufacturing	The feed mechanism will be conveyor chain, belt over chain, or auger

Weight and Material

Respondents reported on the weight and composition of their applicators. Most reported using stainless steel for composition, while Epoke provided additional details that their steel is sandblasted, treated with a zinc primer, and painted. Weight of the applicators varies (Monroe listed 500 – 8,000 pounds empty). Detailed answers are listed in Table 5.8.

Table 5.8. Weight of the applicator systems (empty or dry weight) and primary material from which the hopper is manufactured:

Manufacturer/ Vendor	Weight of applicator and construction material
Henderson	3 types of steel: Grade 50 mild steel, 201 Stainless Steel, 304 Stainless Steel First Response construction: 304 Stainless Steel Munibody and Dump bodies: Grade 50 mild steel, AR400 steel, 201 Stainless Steel, 304 Stainless Steel Blackbelt Maxx: AR400, ar400/201 Stainless Steel Liquid tanks are stainless steel
SnowEx	Most are made of stainless steel. Some models contain heavy duty polyurethane parts.
Hilltip Corp.	Varies on size of machine; 128 – 1200 lbs.; made of hi-mil polyethylene
Epoke	Empty or dry weight will vary depending on size and configuration of the material spreader and its distribution system. Primary material of the hopper is steel which is then sandblasted, treated with zinc primer and then painted. Epoke then backs it with a 10-year rust through guarantee.
Monroe	500 – 8000 pounds pending size of unit (empty). Primary material is stainless steel.
New Leader Manufacturing	Tailgate Spreader – approximately 500 pounds Vee Box Spreader – Weight determined by length and steel gauges – 1,900 to 5,000 pounds Multi-purpose body – 3,800 to 5,500 pounds If you are speaking of liquid systems, the weight can range from 200 pounds to 2,000 pounds. The type of steel can be Carbon, 409 stainless steel, 201 stainless steel or 304 stainless steel.

Warranty

This question sought to find out if the warranty offered by each manufacturer and the answers are detailed in Table 5.9.

Table 5.9. What is the standard warranty for each system and is there an extended warranty available?

Manufacturer/Vendor	Standard Warranty	Extended Warranty Available
Henderson	12 months	Available upon request
SnowEx	2 years	No
Hilltip Corp	2 years from date of purchase	Negotiated
Epoke	1-year parts and labor	Extended warranty and service contracts (including preventative maintenance) are available
Monroe	12 months from date of in-service	Yes, pending contract
New Leader Manufacturing	Warranty period for Hi-Way product is 13 months from date of registration	Yes, an extended warranty can be provided

Cold Weather Operations

This question sought to find out if the manufacturer's systems were able to handle thicker products in extreme cold temperatures and if there are any limitations. The answers are detailed in Table 5.10.

Table 5.10. Will these liquid systems handle the thicker sugar-based products in colder weather? If so, explain limitations.

Manufacturer/Vendor	Will liquid systems handle thicker products in colder weather?	Explain any limitations
Henderson	No performance testing	Depending on viscosities of the liquid material, areas of concern where higher potential of clogging could occur would be in areas such as spray nozzle tips or filter screen.
SnowEx	Unsure. We have tested multiple types of liquids without issue	None reported
Hilltip Corp	Yes, Hilltip products are built in northern Finland and are designed to handle a wide variety of liquid materials in cold temperatures, including pesticides, fire retardants, sanitizers, disinfectants, fertilizers, brine, and sealants.	The limitations to liquid applications depends on the viscosity of the liquid. The denser the material, the more difficult it is for the pumps.
Epoke	The liquid system and pumps are designed to distribute many types of liquids of varying viscosities. Proper maintenance, calibration and cleaning is required.	Can be used with liquids with viscosities of up to 3.2 mPa.s No limitations as long as liquid is not being applied at or below its freeze point.
Monroe	Yes, hydraulic driven gear pumps are better than electric pumps for pre-	Product viscosity and temperature can affect ability to be sprayed

New Leader Manufacturing	wetting application. Most direct liquid applicators utilize centrifugal pumps We do not have experience with these types of liquid on the electric systems. My thoughts are that they would not work well. On hydraulic pumps both standard and slurry type, we have had no issues.	N/A
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Filtering/Screening

Respondents were asked if their systems filter or screen the product being pumped, and if so, what is the filter’s gradation and location. All manufacturers/distributors reported that they do filter their products on the intake side, although Henderson reported one pump that filters on the discharge side. The details are reported in Table 5.11.

Table 5.11. Do these systems filter or screen the product being pumped? Where is the filter or screen location and what is its gradation?

Manufacturer/Vendor	Filter or screen?	Location	Gradation
Henderson	Serviceable screen	Anti-icing/deicing pump uses a centrifugal pump with a filter screen on the discharge side of the pump. Gear pumps used in the lower GPM prewet pumps are gear pumps with a filter screen on the intake side.	Henderson Products liquid systems use a 40mesh screen. Henderson uses Banjo brand screen/housing. Replacements screens are available through Henderson Products or other Banjo fitting retailers. Henderson centrifugal pumps are generally able to accommodate a reasonable amount of debris.
SnowEx	Comes standard with filter	filters are located on the intake	Not reported
Hilltip Corp	Filter or screen	Inlet side	Stainless mesh, need to confirm microns
Epoke	Filter and screen	Pump intake	N/A
Monroe	y-style filer is standard	Intake side of pump	20 mesh
New Leader Manufacturing	Screen type filtration	On the pump intake side	30-50 mesh depending on unit

Respondents who use filters were asked more specific questions about the ease in upkeep, such as the length of time it takes to clean or replace filters, and the tools and skills required to

do so. Table 5.12 provides detailed answers. All manufacturers/distributors reported that cleaning and/or replacing filters was a quick and easy procedure with basic skillsets required.

Table 5.12. How long does it take to clean and/or replace filters, and what are the tools and skillset required?

Manufacturer/ Vendor	How long to clean and/or replace filters	Tools required	Skill set required
Henderson	Cleaning a strainer simply requires removing strainer cap, then screen and washing/brushing debris from screen.	Tools required may include channel locks if filter screen cap cannot be turned by hand	Skills require to unscrew filter cap, clear filter or replace with new, install filter into housing and replace filter cap.
SnowEx		Basic tools	Basic skillset
Hilltip Corp	Less than 2 minutes	None	None
Epoke	5 minutes	Filter wrench	None, ability to use basic tools
Monroe	30 seconds	No tools	Very minimal
New Leader Manufacturing	5 minutes	Caps are normally hand tightened. Spanner wrench can be used if needed	Minimal

Mixing solid material with liquid

This section asked for details on how the solid material is coated with the liquid and how the two are mixed. The mixing procedures differed between systems, and SnowEx reported its own patented procedure shown in a video (link included in the table below). Table 13 provides details on the mixing procedures for each respondent.

Table 5.13. Q. L: 1-4. How is the solid material coated with the liquid?

Manufacturer/ Vendor	L1. How is solid material coated with liquid	L2. Is it sprayed on? Type of nozzle, number, and location?	L3-4. Is it mixed with the solid? How is the liquid placed into the mixing chamber? 4. Where is the liquid placed into the mixing chamber?
Henderson	Mixing differs between systems	Pre-wetting of granular material generally takes place inside the material discharge spinner chute prior to contacting the spinner disc. Henderson’s standard design uses a variable displacement orifice (VDO) inside the spinner chute. The VDO provides improved coverage with less atomization of the	On auger spreaders with a slurry kit, a tube is installed under the granular hoppers inverted vee. The stainless tube has (6) .156 holes which spray liquid above the augers. As the augers convey material, liquid is mixed with the granular to create a slurry mixture prior to

		liquid being applied. The VDO can be best described as a hose with slits that can open/close in size based on the pressure. Henderson also has a traditional spray nozzle configuration as an alternative option. The spray nozzle option replaces the VDO kit with a (2) nozzle tip spray kit. The nozzles use a TG10 type spray tip.	leaving the hopper.
SnowEx	Patented mixing chamber. Video can be seen at https://www.snowexproducts.com/product/helixx-poly-hopper/		The spray bar distributes liquid over the top of the auger and mixes it with the material before exiting the chute
Hilltip Corp	Pump sprays solid material as it leaves the end of the auger and heads down the chute. Some users will spray the material at the spinner	2 fan style nozzles in the upper chute assembly	Liquid is stored in built-in tanks in the hopper. It mixes with solids at the end of the auger or at the spinner. Brine making – bulk material and liquid are mixed in a tank and circulated with 102 gpm pump
Epoke	Depending on how the spreader is configured, it can be coated in the funnel (drop tube), on the spinner, mixing chamber or as it is disbursed on the surface	Nozzles are located either in the funnel (drop tube) just above the mixing chamber or on the back of the unit. Size and quantity varies based on location.	Solid material is gravity fed to mixing chamber while solid is pumped in simultaneously. Liquid is placed into the mixing chamber from a nozzle directly above the chamber
Monroe	Either sprayed on or injected	1-3 Fan-type nozzles, 1-2 gpm per nozzle pending system	Injected – ¾ “ stainless pipe in auger through (typical)
New Leader Manufacturing	Spray nozzle or blended	Liquid is sprayed on and can be applied at the conveyer prior to exiting. Nozzles are typically “flat fan” type; This is typical application for a chain conveyer type machine	For auger machines the material is pumped into the conveyor system. The counter rotation of the augers is used to mix the material with the liquid. On slurry style machines the liquid is deposited through a diffuser onto the spinner disc in the same area as the granular. A special designed hub and spinner disc “mix” or “blend” the material to

provide an even coating of the liquid onto the granular.

Training and Support

Respondents were asked a number of questions about the training and support they provide customers, including the medium used, topics covered, and if hands-on training is included. All manufacturers/distributors provide training to various degrees for their products, as detailed in Table 5.14.

Table 5.14. Training, topics, methods of delivery

Manufacturer/ Vendor	Do you provide training with your systems?	Topics covered	Method of presentation. Include hands-on?	Support documentation distributed as part of training?	Phone or website helpline?
Henderson	Training is provided to end-users upon request.	Topics covered may include calibration, testing, manual/automatic modes, maintenance.	Due to varying system nature from truck to truck, most training is in-person based on the equipment being provided. Yes, hands-on	Support documentation during the sales process primarily includes product literature. All product literature can be downloaded from the Henderson website.	www.hendersonproducts.com. Technical Services can be reached at 800-359-4970.
SnowEx	Our technical support team offers hands-on training for all technical dealer staff every summer before the season starts	Plow and spreader training. Covers operation, troubleshooting and repairs.	In person training with actual product, presentations and hard copy books to take away. Yes, hands-on		Tech Service "800" number for all dealers. We have a well experienced staff of over a dozen professionals that can help customers with any and all issues they may have. They travel the nation in late summer, setting up remote hands-on training for dealer technicians. In a non-covid year we train over 1000 technicians in the field.
Hilltip Corp	Yes	Everything	In-person or	Owners/operator's	Yes, by customer

		from proper operation, maintenance, storage, software training, HTrack, worksite creation and snow/ice mitigation strategies	virtually and augmented with product manuals. Manuals can be provided conditionally.	manuals, service manuals and parts manuals are provided with equipment	demand via phone or email
Epoke	Yes, full training is provided upon delivery	Operation, calibration, preventative maintenance, seasonal maintenance, general maintenance, troubleshooting	Training and support is provided in all versions: classroom, PDF, website, CD or flash drive, video (YouTube)	Both hands on and classroom teaching available	Yes, technical support provided by contacting the Wausau 24-hour service line. Part and support also available online at epoke.dk
Monroe	Via distributor or regional salesman	Typical application rates, travel speeds, calibration and general maintenance	Typically on-site, no video available. Printable literature provided	Yes	Yes. Two in-house service techs to help with hydraulics and Force America Controls
New Leader Manufacturing	Through dealer training or factory assisted dealer training	Calibration, operation and required/recommended service	No answer	PowerPoint and manuals accompany product. Yes, we prefer to do classroom followed up by machine time with dealers	Operation and parts manuals are online.

Training Improvements?

Henderson training programs are comprehensive and adequately cover all necessary training requirements for each product. Additional information can be provided as needed.

SnowEx: We need to provide more video training content for online viewing like YouTube.

Hilltip: Operator ride-alongs during real-time snow events that can better demonstrate the functionality and real-time responsiveness of our systems.

Epoke: By providing both classroom and hands-on training it allows the environment to be interactive giving the attendees the opportunity to be involved, asking questions and actually working with the equipment.

4. Conclusions

Six identified manufacturers/distributors were interviewed or surveyed: Henderson, SnowEx, Epoke, Hilltip Corp., Monroe Truck, New Leader Manufacturing (Hi-Way brand) and Douglas Dynamics, Inc. (Western). Unfortunately, several other manufacturers did not respond to repeated requests to participate in this project.

Some manufacturers sell pre-wet systems to be added to in-use spreaders and some sell spreaders integrated with pre-wetting abilities. Manufacturers build their tanks to fit securely on specific vehicle body types. Some systems are integral to the unit, while others are designed to mount on the sides of the unit, on the tailgate, inside the dump body, externally to the dump body, to the body platform fenders, mounted with brackets to the outside of the dump body sides, or slide into a traditional dump body.

Henderson customizes all its systems to meet the needs of the customer with numerous options. Most systems beyond basic pre-wet use advanced control systems such as Force America, Certified Power, Muncie Power, Dickey John, and many others.

All respondents reported both solid and liquid output for their systems using gallons-per-lane-mile, pounds-per -lane-mile, or pounds-per-minute based on weight of materials.

Most reported having advanced systems for data recording capabilities through the use of plow cams, GPS, and ground surface temperature thermometers. Many systems can monitor routes and track material distributed. These advanced technologies allow for the ability to gather data and adjust application rates as needed.

In terms of feed mechanism, SnowEx uses the patented HELIXX shaftless auger system. Henderson's feed mechanisms included a variety of different systems including pintle chain, roller chain, belt over chain, single auger, and dual auger as well as STD & SS. Epoke uses the "Epoke principle" in their spreader, which includes an agitator to break down the material supplied to the delivery roller.

All manufacturers/distributors provide training to various degrees for their products.

Chapter 6. Conclusions and Knowledge Gaps

1. Conclusions

Pre-wetting is an important tool in the toolbox of WRM operations. This research project collected all available and recent information regarding the pre-wetting practice, through a comprehensive literature review, an online survey of WRM practitioners, interviews and case studies of nine selected agencies, and outreach to six identified equipment manufacturers/distributors. Through the synthesis of current and best practices, the following conclusions can be drawn. Note that these should be treated as preliminary guidelines or recommendations because the pre-wetting practices have been mainly based on trial-and-error and field experience, instead of systematic and scientific investigations.

- 12) There have been many *success stories* of pre-wetting practice by transportation agencies in northern climate, even though few of them produced systematic investigations. The pre-wetted material stays on the surface longer, has less bounce-and-scatter, and resists traffic action. For example, one field test showed 80% of pre-wetted salt remained on a road surface after 100 vehicles traveling at 38 mph, while only 15% remained for dry salt. Pre-wetting also provides faster activation of rock salt turning into a brine and accelerating the ice melting process. Field experience suggested typical savings of 25–30% less salt required when using the pre-wetted salt. Pre-wetted abrasives can reduce the amount of material applied by as much as 50% compared with dry abrasives in low temperatures. Field tests showed that the pre-wetted sand resulted in higher friction improvement (as high as 187%) than dry sand when used at the same application rate. The case study agencies also reported that pre-wetting allowed them to achieve the specified LOS quicker.
- 13) On the *most reasonable materials*: Salt brine (23 wt.%) is the most commonly used liquid for pre-wetting of rock salt and abrasives, and 30 wt.% $MgCl_2$ and 32 wt.% $CaCl_2$ are popular alternatives in low temperatures when salt brine becomes less effective. Other additives (e.g., corrosion inhibitors and agricultural by-products) can be admixed into chloride brines to reduce the corrosivity of the brine or enhance the snow/ice control performance of the pre-wetted salt. Beet juice has been increasingly used as a performance enhancer of salt brine, typically at 30% by volume, for pre-wetting and deicing.
- 14) On the *most reasonable liquid-to-solid pre-wetting rates*: In theory, only enough liquid to wet every particle of a dry material is required for pre-wetting. The actual rate to achieve this wetting will vary with the particle size distribution of the solid, but 8–12 gal/ton is effective and 8–16 gal/ton is reasonable for increasing the speed and total ice melting capacity of solid salt and reducing the snow-pavement bond. Practitioners have

reported that higher pre-wetting rates (than 10 gal/ton) can achieve better operational results (less bounce-and-scatter and faster salt activation), thus reducing the amount of granular salt needed. For trucks equipped with pumps to make salt slurry, a higher pre-wetting rate (30 to 50 gal/ton) can be achieved. A higher application rate should be used when there is a lower pavement temperature or a more severe snow event. Field tests have suggested that pre-wetting is not necessary at relatively high pavement temperatures and a low application rate is preferable if pre-wetted salt is used under this condition. A greater pre-wetting application rate may be needed for abrasives than for salt.

In practice, the pre-wetting rate may be limited by factors such as tank capacity, truck's capability, and pump capacity, and may need to be customized as a function of road temperature, traffic volume, precipitation rate and type, cycle time, and other operation conditions. The application rate of pre-wetted salt typically ranges from 100 to 300 lbs per lane mile, whereas that of pre-wetted abrasives could go up to 800 lbs per lane mile.

- 15) On the most reasonable procedures and equipment: All survey respondents reported the use of on-board system to apply liquids to solids. The truck-mounted brine spraying equipment is typically comprised of a liquid tank, pump system, spray bar, and controller. Some manufacturers sell pre-wetting systems to be added to in-use spreaders and some sell spreaders integrated with pre-wetting abilities. The most effective way to deliver pre-wetted salt is a cross conveyor while the truck travels at 25 mph, and the spreader ground speed on interstates could go up to 35 mph. Most survey respondents apply the pre-wetting liquids just prior to the spinner, followed by in the chute and at the auger (esp. to obtain a slurry mixture). Pre-wetting on top of the chain (before the salt enters the chute) or in the auger works better for salt to achieve the saturation condition than at the spinner, although this can cause corrosion issues.
- 16) On the common delivery systems: Pre-wetting equipment can involve a variety of liquid delivery systems and spreader configurations. The easiest on-board pre-wetting process is spraying or streaming liquid material onto the spinner plate, where the spinner plate, liquid application nozzles, and controller capabilities can be modified or adjusted to achieve the optimal efficiency of the pre-wet process. The solid material can be pre-wetted as it passes over the spinner casting disk. Another type of on-board pre-wetting process entails the spreading of solid and liquid materials simultaneously before they hit the road. The liquid emitter tubes have a directional valve to control the spray pattern. Also, the liquid emitter tubes revolve in sync with the spinner disk thus creating a more uniform mixing of liquid and solid materials as they are applied. It is desirable to include an agitator in the feed mechanism to break down the solid material supplied to the delivery roller.
- 17) On the type of pumps to use: The majority of the survey respondents reported that their agency switched from electric pump to hydraulic pump so as to allow for the application of higher rates. Hydraulic pumps are also preferred by some DOTs because they are easy to calibrate or less prone to corrosion issues (and thus require less maintenance or

spreader down time). But the Washington State DOT prefers electric pumps and has successful user experience of approximately 10 years; relative to hydraulic pumps, these electric pumps provide more volume and are less expensive, easier to maintain, and easier to adjust. Some DOTs now use gravity feed system for pre-wetting, so that no pumping is needed and no more concern over the maintenance of pumps.

Generally, old trucks are equipped with electric pumps that provide a *flow rate capacity* of about 5–7 gallons per minute (GPM), whereas newer trucks equipped with hydraulic-driven pumps that provide a flow rate capacity of 10-18 GPM (which is needed for slurry applications).

- 18) On the *type of spreader configurations*: The survey respondents reported the following types of spreader configurations commonly used by their agencies: 1) zero velocity spinner/spreader; 2) front discharge with conveyor chain; 3) wheel track sprayer; 4) tailgate spreader; 5) v-box spreader with chain conveyor; 6) rear discharge spinner; 7) center discharge spinner with V-hopper; and 8) saddle tank gravity to spreader spinner. *Zero-velocity spreaders and pre-wetting techniques yielded bare pavement in half the time of standard methods, while reducing salt use by 70% and salt cost per mile by about 50%.* However, there is no good way to spread sand with zero-velocity spreaders.
- 19) On the *nozzle type, hose size and screen size*: The fan nozzle is the most common used type, mainly because it can lead to a more uniform coverage. Stream nozzles are also used by many agencies, because they allow the liquids to be more focused on solids and thus are perceived as more effective. For pre-wetting, only 1–4 nozzles are needed for the solids on the chute or spinner, and the most common hose size is 1-inch in diameter. The screen size of the pre-wetting equipment ranges from 16 mesh to 80 mesh, and as small as possible (without being easily clogged).
- 20) On the *reliability/maintainability/safety issues of on-board systems*: The pre-wetting equipment can be at least just reliable as other WRM equipment, given regular maintenance and calibration. Yet, the reliability of pre-wetting equipment depends on operators or circumstances and there could be issues with liquid delivery pumps. It is crucial to keep pre-wetting equipment maintained, especially at the end of the season as well as calibrating at the beginning of season. For example, the nozzle tends to plug and should be cleaned regularly; system flushing and screen cleaning are required at least twice per season. How water sanding help melt just enough of the snow-pack so that the abrasives stay on the road longer. But this technology could significantly reduce visibility, resulting in a safety concern for following traffic.
- 21) On the *implementation of pre-wetting practice*: Agencies may face initial resistance to pre-wetting from operations staff or other stakeholders, but training and information dissemination coupled with effective field trials will gradually mitigate concerns and build rapport. Some obstacles for agencies transitioning to pre-wetting may include cost, equipment, capacity, logistical challenges, and worker availability.
- 22) On the *recent developments*: New on-vehicle tools (e.g., zero-velocity spreaders and modified spinners) facilitate precise and effective applications of both solid and liquid

materials. Yet another new technique is the use of pre-wetted fine graded salt, i.e., the spreader mounted on the truck crushes or mills salt in ordinary size into fine size, which results in a substantially longer durability of the salt on pavement (especially on dry or moist road surfaces).

During the past decade, the most common change by transportation agencies is the increased use of liquid. As a result, the liquid application equipment has also changed, such as larger pre-wetting tanks, increased pump size, and increased flow rate. Some agencies are also switching the pre-wetting location from the spinner to the chain or auger. Most of the responding agencies use technologies such as RWIS, AVL or MDSS to aid in determining when and how to use pre-wetting. Most equipment manufacturers reported having advanced systems for data recording capabilities through the use of plow cams, GPS, and ground surface temperature thermometers. Many systems can monitor routes and track material distributed. These advanced technologies allow for the ability to gather data and adjust application rates as needed.

For the *case study agencies*, all of them have changed their pre-wetting practices since first implementation based on increased understanding, support, and better equipment and technologies. They have increased capacity, better training, and positive community backing, and most have also upgraded equipment to include larger capacity, bigger volume and hydraulic pumps, spray nozzles, ground speed sensors, and live bottom v-boxes. Some agencies are considering changes such as purchasing pre-treated salt, slurry application, and a reliable management system in vehicles. Agencies frequently have multiple generations or versions of equipment as older truck are incrementally replaced. Typically, replacement schedules can range from 7-20 years or longer.

2. Knowledge Gaps

Through the synthesis of the information collected in this project, the following knowledge gaps or research needs can be identified.

- 4) There is a lack of scientific and quantitative knowledge on how various factors influence the costs and benefits of pre-wetting practice, for typical road weather scenarios. Most survey respondents reported that pre-wetting can lower the total cost of WRM operations, in terms of materials, equipment, and labor. However, the majority of them have not yet conducted the cost-effectiveness or cost-benefit analysis.
- 5) The scientific or quantifiable evidence of effectiveness underlying the specific pre-wetting operation, especially the pre-wetting application rate, is lacking and there is an urgent need to study and optimize both the appropriate pre-wetting rate of liquid-to-solid and the appropriate application rate of the pre-wetted salt for the typical road weather scenarios. The optimal rates are likely a function of climatic conditions, pavement surface conditions, traffic volume and speed, particle size distribution of solid

material, type of pre-wetting liquid, methodology for pre-wetting, equipment type/configuration, groundspeed of the spreader vehicle, etc. Looking to the future, such knowledge gaps should be addressed by experiments in the laboratory as well as field operational tests to be designed and executed during Phase II.

- 6) For Phase II, one needs an experimental design that is statistically valid and practically feasible, in terms of field evaluation of the impacts of different pre-wetting equipment/configurations, materials, and rates on the effectiveness of pre-wetting. A multi-state testing program is needed to provide a reasonable representation of diverse road weather scenarios, equipment, liquid and solid products, etc. seen in the Northern States. Field testing should be conducted to assess the effects of various pre-wetting liquid-to-solid application rates and specific liquid products to: (1) reduce bounce and scatter, (2) reduce overall salt application rates, (3) improve friction, (4) reduce the time to regain bare pavement, (5) reduce corrosion to metals on equipment, and (6) increase the longevity of winter traction materials under variable speed traffic.

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Appendix A. Project Interview Questions

A. Interviewee Information

Name _____
Agency _____
Title _____
email: _____
Preferred interview method: in-person _____ phone (#) _____ Zoom/Skype _____

B. Agency Characteristics

1. Size in sq. miles/ kilometers of jurisdiction _____ Population of jurisdiction _____
2. Total center-lane miles (agency responsibility) _____
3. Total as lane-miles (agency responsibility) _____
4. Center or lane-miles (By FHWA Road Classification)

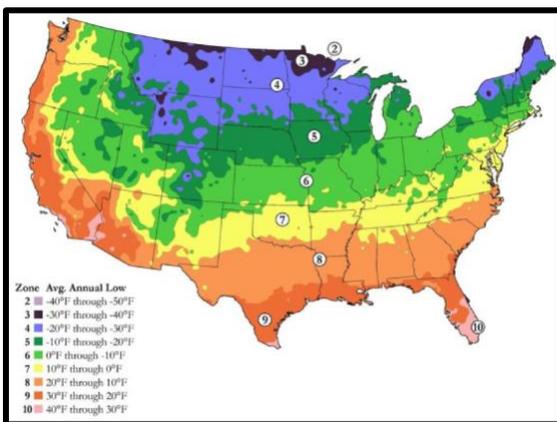
(https://www.fhwa.dot.gov/planning/processes/statewide/related/highway_functional_classifications/section03.cfm.)

Interstate _____ Freeways/ Expressways _____ Principal Arterials _____ Minor arterials _____
Collector _____ Paved local rural road/ Urban street _____ Alternate: Agency's own classification if preferred: _____

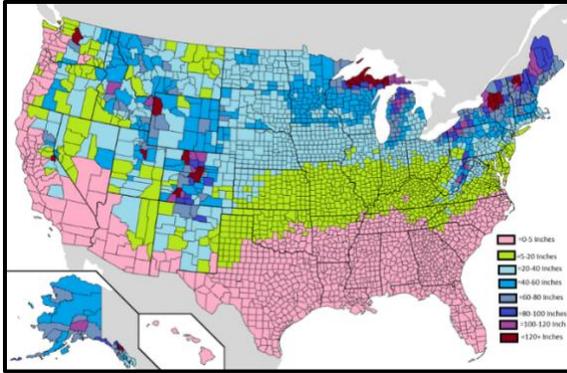
5. Predominant terrain (AASHTO classification definitions): Level _____ Rolling _____
Mountainous _____

Any situations that require special attention (i.e. long-span bridges, tunnels, roads along shorelines, etc.)? Notes:

6. Climate zone (see chart). Notes:



7. Average annual snowfall (per chart) or actual records if significantly different. Notes:

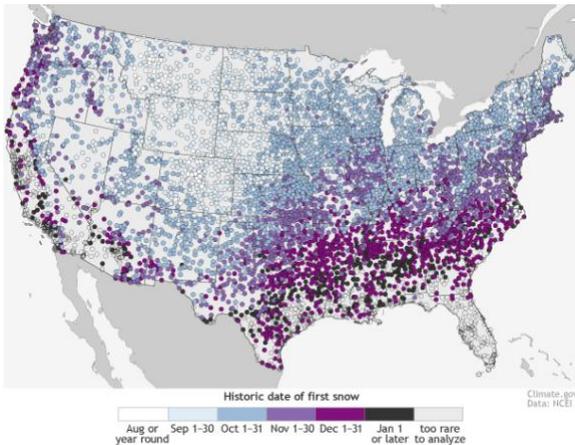


8. Annual number of snow events requiring treatments

9. Annual number of ice (frost, black ice, freezing rain) requiring treatment. Notes:

10. Approximate historical date of first snowfall (per chart) or actual if significantly different

11. Approximate historical date of last snowfall requiring treatment. Notes:



C. Interview / Case Study Questions:

1. What dry materials does your agency routinely use:

Rock salt ___ sand ___ salt/sand mix ___ other _____

2. What liquid materials do you use for pre-wetting:

CaCl₂ ___ MgCl₂ ___ Straight salt brine ___ Brine mix (specify components) _____

Corrosion inhibitors added: _____ Notes: _____

2.a) Does your agency make its own brine? ___ If yes, what equipment is used?
 _____ What is the storage capacity? _____

3. What is your agency’s method of pre-wetting materials (check any that apply):

Purchased already pre-wetted ___ Pre-wet in Stockpile ___ “Shower-spray” at loading
 ___ On-board _____

Are all the spreader trucks in your fleet equipped with on-board pre-wet capability? _____

For trucks without on-board pre-wetting: how effective is stockpile pre-wetting, or “shower-spray” at loading vs. on-board pre-wetting? _____

4. Level of Service (LOS):

A copy of the agency’s LOS (or link to this information) for all road classifications is requested.

Application rates and when initial spreading begins for each classification:

Interstates/ freeways _____

Major surface arterials _____

Minor arterials _____

Collectors _____

Low-volume roads/ streets _____

Notes _____

5. Pre-Wet used for:

Pre-treatment _____ Every winter event _____ Depends upon individual event _____

6. Reasons for pre-wetting:

Reduces material usage _____ faster deicing action _____ reduces environmental impact _____

Other _____

7. a. How long has your agency been practicing pre-wetting? _____

b. What were the reasons for doing so? _____

8. Did your agency conduct any tests or trials when initially considering or implementing pre-wetting?

9. What sources of information did your agency utilize in learning about pre-wetting ?

APWA conferences _____ AASHTO conferences/ webinars _____ TRB conferences/ webinars _____

NCHRP reports _____ Clear Roads project reports _____ PIARC conferences/reports _____ Vendors/ manufacturers of products and equipment _____

Discussions with other agencies/ peers _____ Other (specify) _____

10. Has your agency’s pre-wet practices changed since initial implementation; if so, how and why?

11. Was the implementation gradual or “all-in” at onset?
12. What changes in equipment have been made?
13. What was the reaction from the operations staff to the introduction of pre-wetting?
14. Was additional training and information needed to gain their acceptance?
15. Was there initial resistance or skepticism from higher levels within the agency or from elected officials?
16. What other obstacles or impediments did the agency face in transitioning to pre-wetting?
17. What has been the reaction by the public to your agency’s pre-wetting operation?
18. Did your agency publicize or otherwise inform the public and media of the use of pre-wetting?
19. Has your agency revised or modified levels of service since implementing pre-wetting?
20. What is your evaluation/assessment of pre-wetting so far?
21. What changes to pre-wetting practices/methods and materials is the agency considering?
22. Other comments/insights/advice?

Additional equipment questions

1) How many spreader trucks in your fleet have on-board pre-wet capability?

Type	Number	Model Year Range
½ -3/4 ton		
1-ton		
Super duty (commercial class 4,5,6)		
Single-axle dump (commercial class 7)		
Tandem-axle dump (commercial class 8)		
Tri-axle dump		
Other		

2)a. What are the make/ model of all your on-board pre-wet equipment (including controllers)?

b. Have you used other equipment in the past? If so, what make/ models and describe your experience/satisfaction with that equipment

c. Have you considered other models for future purchases? If so, which ones and why?

3) On-board pre-wet equipment maintenance and calibration

a. What maintenance is needed to keep pre-wet equipment functioning (flushing, screen cleaning, etc.)?

b. How often do you calibrate the solid and liquid delivery systems, and how long does it take?

4) Groundspeed of spreader vehicle: recommended vs maximum? Do you enforce a maximum speed limit?

5) Does your agency utilize telematics (GPS, AVL, mobile computers, etc.) to track/ monitor application times and rates?

Appendix B. Case Study Questionnaire Answers

A. Interviewee Information

Table B.1. Agency contact names, position, and agency.

Agency	Contact	Agency Name
Idaho Transportation Dept.	Steve Spoor, Maintenance Services Manager	Idaho Transportation Department
Illinois, McHenry County	Ed Markison, Maintenance Superintendent	McHenry County Division of Transportation
Massachusetts DOT	Mark Goldstein, Lead State Snow & Ice Engineer	Massachusetts Department of Transportation
Lexington/MA	Marc Valenti, Manager of Operations	Town of Lexington Dept. of Public Works
Farmington Hills, MI	Bryan Pickworth, Road Maintenance Supervisor	City of Farmington Hills, MI-DPW
Montana DOT	Bob Cloninger, Maintenance Review Supervisor	Montana Department of Transportation
North Dakota DOT	Barry Kinnischtzke, Transportation Engineer	North Dakota Department of Transportation
Oregon DOT	Scott Rattay, Winter Maintenance Program Coordinator	Oregon Department of Transportation
Vermont DOT	Brian Roberts, General Manager	Vermont Agency of Transportation

B. Agency Characteristics

Q. 1-3. A total of nine agencies participated in the case studies interviews representing eight different U.S. states and agencies including Idaho, McHenry County Illinois, Massachusetts, City of Lexington, MA, City of Farmington Hills, Michigan, Montana, North Dakota, Oregon, and Vermont.

Table. B.2. Agency characteristics (Questions 1-3)

Agency	Q 1. Sq miles/kilometers	Population of jurisdiction	Q 2. Total center-lane miles	Q 3. Total as lane miles
Idaho Transportation Dept.	83,642	1.8 million	5,132	13,889
Illinois, McHenry County	611	308,000	224	530
Massachusetts DOT	10,565 mi-2	6,893,000	3008.7	9,551.32
Lexington, MA	16.5	32,000	151	284
Farmington Hills, MI	33	80,000	308	647.9

Montana DOT		1.069 million	12,927	25.854
North Dakota DOT	70,704	762,000	7,417	17,267
Oregon DOT	Not reported	Not reported	8029	19,090
Vermont DOT	9,220	624,000	3,453	6511

Q 4. Agency center lane miles (by FHWA road classification)

Table B.3. Number of miles per state for various road classifications

Agency	Interstate	Freeways Expressways	Principal arterials	Minor arterials	Collector	Paved rural/urban
Idaho Transportation Dept.	611	140		2136	6173	40,987
Illinois, McHenry County	-	-	16	56	129	23
Massachusetts DOT	572.34	-	2190/74		190	55.62
Lexington, MA	-	-	Yes, # not specified	Yes, # not specified	Yes, # not specified	Yes, # not specified
Farmington Hills, MI	-	-	167.9	480	-	-
Montana DOT	1192					432
N. Dakota DOT	571	-	3106	2,545	1153	42
Oregon DOT	-	-	-	-	-	-
Vermont DOT	320.3	17.7	456.1	882.7	3154	9260.1

Alternate: Montana 2,993 non-interstate NHS; 2,646 Primary; 4,506 Secondary; 1,158 state highway; all center lane miles

Q 5-7. Terrain, climate zone, average annual snowfall

Table B.4. Characteristics: terrain, climate one, and average annual snowfall.

Agency	Q 5. Dominant Terrain	Q 6. Climate Zone	Q 7. Avg Annual snowfall
Idaho Transportation Dept.	Mountainous	5/6	Up to 120 inches per year but as low as 5 in some areas
Illinois, McHenry County	Level	5	34-36 inches
Massachusetts DOT	All	Primarily 6 with a small portion of 7	Varies with elevation
Lexington, MA*	Level, rolling	6	60 inches
Farmington Hills, MI	Rolling	6	20-40 inches
Montana DOT	Mountainous	east of the Continental Divide is mainly 4, while west is 5 and 6	5-80 inches

N. Dakota DOT	Level	4	50 inches
Oregon DOT		6-8	
Vermont DOT		4/5	40-60 inches

*Note: Lexington noted elevation changes east to west, creating microclimates.

Q 8-11. Number of snow events requiring treatment, number of ice events requiring treatment, historical date of first snowfall of the year, historical date of last snowfall of the year.

Table B.5. Snow events

Agency	Q 8. # snow events requiring treatment	Q 9. # ice (frost, black ice, freezing rain) requiring treatment	Q 10. Historical date of first snowfall of the year	Q 11. Historical date of last snowfall of the year
Idaho Transportation Dept.	60	As little as 5-6 to triple digits	Any time of year depending on location	May 1
Illinois, McHenry County	40-70	5	October 31	March-April
Massachusetts DOT	25-30	2-3, but more recently 5-6	October 1-31 in the hills of Berkshires and Worcester. Normally Nov 1-30 elsewhere.	Early April to early May depending on location
Lexington, MA	25	Not reported	November	April
Farmington Hills, MI	35		October 31	April 15
Montana DOT	29	6.26 days	Year-around	Year-around
N. Dakota DOT	Not tracked	Not tracked	Mid October	Track until May
Oregon DOT	Not tracked	Not tracked	Not tracked	Not tracked
Vermont DOT	Not tracked	Not tracked	Mid to late October	May

Case Study Questions

1. What dry materials does your agency routinely use?

Table B.6. Dry materials and mixes used by state agencies.

Agency	Rock Salt	Sand	Salt/sand mix
Idaho Transportation Dept.	Used	Used	3:1 ratio
Illinois, McHenry County	Treated salt either Thawrox or Clearlane	-	-
Massachusetts DOT	Used	not much, mainly used in the hilly areas and reduced salt zones where the salt would go	1:1 mix, typically at 240 lbs./lane-mile, i.e., 120 lbs. salt and 120 lbs. of sand

			directly into water bodies	
Lexington, MA	Used		Not used	Not used
Farmington Hills, MI	Used		-	chloride treated sand for gravel roads
Montana DOT	Used		Used	Used
North Dakota DOT	Used		Used	Used
Oregon DOT	Used		Used	-
Vermont DOT	Used		Used	Used

2. What liquid materials do you use for pre-wetting?

Table B.7. Wet materials used by agencies and mix ratios.

Agency	CaCl ₂	MgCl ₂	Straight Salt Brine	Brine Mix
Idaho Transportation Dept.	Not used	Used	Used	Boost is added in some districts to deal with colder temps
Illinois, McHenry County	Not used	Not used	Not used	80% salt brine 20% organic
Massachusetts DOT	Not used	Used	Not used	Earlier, we discussed the perceived benefits of using MgCl ₂ to pre-wet solid salt, as MgCl ₂ being exothermic and can give heat to the salt
Lexington, MA	Not used	Not used	Not used	Brine/Carbohydrate
Farmington Hills, MI	Used	Used	Used	brine mix with Geomelt at 10-20%
Montana DOT	Not used	Used	Used	Not used
North Dakota DOT	Not used	Not used	Used	Brine mix SB80: Geomelt20 (which is beet juice concentrate)
Oregon DOT	Not used	Used	Not used	Not used
Vermont DOT	Not used	Used. This is a commercial product, Promelt we purchase and apply for pre-wetting at the spinner	Used	Not used

Corrosion inhibitors added:

Table B.8. Corrosion inhibitors

Agency	Corrosion Inhibitors added
--------	----------------------------

Idaho Transportation Dept.	None to brine, but MgCl ₂ is purchased with inhibitor added
Illinois, McHenry County	Yes, De-ice 55. Can add CaCl ₂ in extreme cold events
Massachusetts DOT Lexington, MA	IMP-AP (.8%) 90/10, 85/15, 80/20 blends
Farmington Hills, MI	Pilot on a corrosion inhibitor during 20/21 season as time allows
Montana DOT	Yes, currently MDT requires all deicers to be inhibited
North Dakota DOT	None
Oregon DOT	Yes
Vermont DOT	None

2a) Does your agency make its own brine? If yes, what equipment is used?

Table B.9. Brine equipment used.

Agency	Own brine and equipment used
Idaho Transportation Dept.	Variety of brine manufacturers located in 9 different locations, Coeur d’Alene, Fish Creek, Twin Falls, Shoshone, Pocatello, Downey, Soda Springs Rigby, Salmon
Illinois, McHenry County	Brine extreme capable of making 6,000 gallons/hr.
Massachusetts DOT Lexington, MA	Yes. Henderson Brine Extreme
Farmington Hills, MI	Yes, Accubrine 2011-2020; 2020-present Brine Masters Continuum BM-6
Montana DOT	Yes, Henderson Infinity
North Dakota DOT	Yes, we have one Henderson Brine Extreme Ultimate and four VanTech SB 600 brine makers. The VanTechs were the first ones used and have moved to the Henderson as technology has advanced.
Oregon DOT	Yes. Henderson Brine Extreme
Vermont DOT	No
	Yes, we also call it liquid salt. 23 wt.% NaCl. Typical pre-wetting rate at 8 to 10 gallons/ton, up to 15 gallons/ton. We use Henderson’s Brine Extreme™

2b). What is the storage capacity?

Table. B. 10. Brine storage capacity per state.

Agency	Storage Capacity
Idaho Transportation Dept.	about one million gallons at 9 different sites
Illinois, McHenry County	150,000 gallons = 10 - 15,000-gallon tanks. Also have the ability to get material from satellite townships and municipalities. With this we can get material at 10 site in addition to our own. Material must be replaced within 72 hours of event ending. Worst case scenario, we never have to travel more than about 15 miles to reload. In some cases as little as 5 miles.

Massachusetts DOT 310,000 gal. (statewide)
 Lexington, MA 12,000 brine; 12,000 carbohydrate
 Farmington Hills, MI 3,000 brine, 12,000 Geomelt, 18,000 to store 32-38% calcium chloride for winter & summer
 Montana DOT Varies per production site; 30-120,000 gallons
 North Dakota DOT A little under two million gallons. A bit of history: we started with just salt brine, which tends to freeze at -6F or so and we started to get frozen and broken pump and valves. So we started to add the Geomelt which brought the liquid's freezing
 Oregon DOT Does not store brine
 Vermont DOT 810,000 gal. (for my district, D1, which is southern and remote); 43k gal (D2); 130k gal (D3); 120k gal (D4); 176k gal (D5); no D6 anymore; 84k gal (D7); 133k gal (D8); 66k gal (D9)

3. What is your agency's method of pre-wetting materials (check any that apply):

Table B.11. States' pre-wetting methods.

Agency	Purchased already pre-wetted	Pre-wet stockpile	Shower-spray at loading	On-board
Idaho Transportation Dept.			Very few shower sprays left; being replaced since ITD does not believe this method works well for them.	Used
Illinois, McHenry County				Used
Massachusetts DOT	Planning to experiment in near future			Used (also discussed choice of pumps; they preferred hydraulic pumps over electric pumps because the former is less susceptible to failures.)
Lexington, MA				Used
Farmington Hills, MI				Used
Montana DOT		Used		(as-built 6 gal/yard, on-board).
North Dakota DOT				Used
Oregon DOT		Used		Used
Vermont DOT		Used (Also discussed the population of Vermont is		

slightly more than half million. An older product MagicMinusZero contained molasses and was able to better bind the solid salt, but that product was discontinued due to political reasons)

Are all the spreader trucks in your fleet equipped with on-board pre-wet capability?

Table B.12. States’ equipped spreader trucks with on-board pre-wet capability.

Agency	Spreader trucks in fleet equipped with on-board pre-wet capability?
Idaho Transportation Dept.	Yes, Stockpile pre-wetting, or shower spray is not well liked by the ITD and is considered ineffective
Illinois, McHenry County	Yes
Massachusetts DOT	All Contracted Spreaders are (83% of overall fleet are contractors, or 1,267 Spreaders). Many of our own Spreaders lack pre-wetting capability. We are trying to address this as an agency. Our spreaders number 256 (17% of overall spreader fleet)
Lexington, MA	Yes
Farmington Hills, MI	Yes
Montana DOT	No, 85%. Pre-wetting a stockpile will keep it manageable and do almost everything on-board prewetting will do. The biggest differences are prewet volume adjustments for storm collections and possible leaching issues and material loss in a pre-wet stockpile
North Dakota DOT	Yes
Oregon DOT	No Stockpile pro-wetting is not routinely used, not as effective as on-board pre-wet
Vermont DOT	Yes, All (but some districts such as D2 chose NOT to pre-wet on-board even though their equipment was equipped with this capability; due to challenges to access municipal water and only had wells).

4. Level of Service (LOS):

Application rates and when initial spreading begins for each classification:
Interstates/ freeways

Massachusetts	240
Farmington Hills, MI	300-400# per lane mile depending on road temps
Montana	6-8 gallons/ton
N. Dakota	40-60 gal/ln mi, 100-200 lb/ln mi, depends on event

Major surface arterials

Massachusetts	240
Lexington, MA	DLA-50 gal/mi; 100-250 lbs/mi based on event
Farmington Hills, MI	300-400# per lane mile depending on road temps
Montana	6-8 gallons/ton
N. Dakota	40-60 gal/ln mi, 100-200 lb/ln mi, depends on event

Minor arterials

Massachusetts	240
Lexington, MA	DLA-50 gal/mi; 100-250 lbs/mi based on event
Farmington Hills, MI	300-400# per lane mile depending on road temps
Montana	6-8 gallons/ton
N. Dakota	40-60 gal/ln mi, 100-200 lb/ln mi, depends on event

Collectors

Mass	240
Lexington, MA	DLA-50 gal/mi; 100-250 lbs/mi based on event
N. Dakota	40-60 gal/ln mi, 100-200 lb/ln mi, depends on event

Low-volume roads/ streets

Massachusetts	240
Lexington, MA	DLA-50 gal/mi; 100-250 lbs/mi based on event
Montana	6-8 gallons/ton
N. Dakota	40-60 gal/ln mi, 100-200 lb/ln mi, depends on event

Notes

Massachusetts: We need to address our never-changing application rate.

North Dakota: Pretty consistent across different roadways; but Interstate may see more frequent treatments. We got some wide range of benchmarks we aim for, such as nearly bare pavement within a given time frame. Will share the document that outlines these. Throughout the season, about 50 tons of salt over the 17,267 (total) lane miles.

Vermont: The average rate is 250 to 300 lbs. per lane mile. Application rates, how and when they should be applied are determined by the local area supervisor with some guidance from district General Manager. Each storm and the road surface will have their own elements which will determine how the supervisor will treat or choose not to treat the travel portion of the roads according to the Snow and Ice Control Plan. Each Route is designated a priority level of

service determined by traffic volumes. Orange being the highest level of service to Yellow the lower level. All are depending on resources at hand. Snow and Ice Control Plan also outlines how each route should look immediately following an event.

Montana: Storm events dictate application rates

Illinois, McHenry County: Bare pavement ASAP after event is over. All roadways are between 50-200 lbs/mile or 65 gallons/mile for liquid routes, at 10 to 20 GPT based on weather conditions

Farmington Hills, MI: When using Direct Liquid Application of various blends of salt brine 40-70 GPLM

5. Pre-Wet used for:

Table B.13. State’s pre-wet uses.

Agency	Pre-wet used for
Idaho Transportation Dept.	Pre-treatment; every winter event
Illinois, McHenry County	Pre-treatment, every winter event
Massachusetts DOT Lexington, MA	Depends upon individual event (vast majority of events) Every winter event
Farmington Hills, MI	Yes, Every winter event, Henderson Infinity
Montana DOT	Pre-treatment, every winter event, depends upon eventual event
North Dakota DOT	Depends upon individual event; more frequently than not, we try to push that as policy
Oregon DOT	pre-treatment, depends on individual event
Vermont DOT	Every winter event (by policy except D2 unable to access water)

6. Reasons for pre-wetting:

Table B.14. Agency reasons for pre-wetting.

Agency	Reduces material usage	Faster de-icing action	Reduces environmental impact	Other
Idaho Transportation Dept.	X	X	X	
Illinois, McHenry County	X	X	X	
Massachusetts DOT	X	X	X	We pre-treat roadways (anti-icing, usually 20-30

gallons/ln-mi) when a storm promises to come in white. If it looks to come in as rain, we will not pre-treat to not waste the treatment into the storm drain. We usually use a blended brine, which is 85% of our own saturated NaCl brine and 15% of the 28% MgCl2.

Lexington, MA	X	X	X
Farmington Hills, MI	x	x	x
Montana DOT	X	X	X
North Dakota DOT	X	X	X
Oregon DOT			
Vermont DOT	X	X	X

Less bounce and scatter
Material retention

7a. How long has your agency been practicing pre-wetting?

7b. What were the reasons for doing so?

Table B.15. History and reasons for pre-wetting. Q 7a-7b

Agency	7a. How long practicing pre-wetting	7b. Reasons for pre-wetting
Idaho Transportation Dept.	25+ years	Same as answer "a"
Illinois, McHenry County	Since mid-1990s; 20+ years	Salt activation, bounce and environmental impacts
Massachusetts DOT	Since about 2011	Reduce bounce-and scatter; activate the salt crystal to work to create brine as soon as it hits snow and ice; lessen environmental impacts and MgCl2 lends heat to the overall reaction because it acts exothermically, whereas NaCl is endothermic and actually takes heat away from the environment
Lexington, MA	Since 2012	It's what is needed
Farmington Hills, MI	30+ years	Improved level of service, save on material, reduce environmental impact
Montana DOT	20+ years	Same as answer "a"
North Dakota DOT	20+ years	Same as answer "a"

Oregon DOT	15+ years	Increase efficiency/effectiveness
Vermont DOT	Full implementation since about 2009; but D5 first experimented in late 1990s and had success	Same as answer "a"

8. Did your agency conduct any tests or trials when initially considering or implementing pre-wetting?

Table B.16. Tests and trials before implementing pre-wetting.

Agency	Conducted tests or trials?
Idaho Transportation Dept.	Yes, many over the years
Illinois, McHenry County	Yes, we did a bounce test on a remote roadway that had boxes painted on the surface.
Massachusetts DOT	I cannot say for sure, but Paul Brown got us into Clear Roads, and the Best Management Practices we have adopted since joining Clear Roads have substantially benefitted our overall program.
Lexington, MA	No
Farmington Hills, MI	Networking with other cities/agencies
Montana DOT	Yes
North Dakota DOT	Neither of us were around; not aware of any formal trials done, no report available.
Oregon DOT	Not to my knowledge
Vermont DOT	No. D5 experimented and the trials were successful. Various trials such as slurry application (not successful) and application of pre-wet salt at the centerline in advance of the storm (solid product for anti-icing, successful in some scenarios)

9. What sources of information did your agency utilize in learning about pre-wetting?

Table B.17. Sources of information utilized for information about pre-wetting.

Agency	Clear Roads Project Reports	Vendors/manufacturers	Discussions with Peers	APWA	AASHTO	TRB	NCHRP	PIARC
Idaho Transportation Dept.	x				x	x	x	
Illinois, McHenry County	x	x	x	x	x	x	x	x
Massachusetts DOT	x	x	x					

Lexington, MA*	x	x	x	x	x			
Farmington Hills, MI	x			x	x	x		x
Montana DOT	x	x	x					
North Dakota DOT	x	x	x	x	x	x	x	x
Oregon DOT	x		x				x	
Vermont DOT	x	x	x					

*Other – LTAP seminars

10. Has your agency’s pre-wet practices changed since initial implementation; if so, how and why?

11. Was the implementation gradual or “all-in” at onset?

Table B.18. Changing pre-wetting practices. Q 10-11

Agency	10. Pre-wetting practices changed?	11. Gradual or “all-in” at onset
Transportation Dept.	Yes, initially experimental, then optional and now mandatory, and now operators follow BMPs	Gradual
Illinois, McHenry County	Yes, prior to pre-wetting we averaged 15,000 tons of salt/year & now we average 9,000 tons of salt/year and are progressing downward through training, better equipment, forecasts & buy in from staff	Gradual, initially only trying 1.2 the county and the whole county the following year but with small tanks
Massachusetts DOT	Yes, we used to use 30% MgCl ₂ , but KCl fallout can happen at warm temperatures (40 deg. F) if contaminant KCl is present in the liquid mag at 0.4% or greater. We switched to 28% liquid mag because the KCl fallout will not happen until it is very cold (about -2 deg. F	It is gradual. We told our Vendors what they were to do, but with our seasoned staff, we are working hard to distinguish MgCl ₂ as a pre-wetter, as opposed to a pre-treater (i.e., anti-icer). Many years ago, some of our veteran folks had trouble with liquid mag as a pretreatment because roads were too warm and the hygroscopic MgCl ₂ took humidity from the atmosphere and deposited it on the roadway, slickening the roads. Liquid mag for pretreatment is only appropriate on below-freezing roadways at 20-30 gal/ln-mi. However, as a pre-wetter for salt, 8 gal/ton is only about 1 gal/ln-mile at a salting rate of 240 lb/ln-mi. and should work fine.
Lexington, MA	Yes, we are more comfortable with products and have better equipment	All-in

Farmington Hills, MI	Mid 80's to 95' Overhead shower bar, 95'-04' @ spinner with fan nozzles, 05'-13' @ spinner or in chute for live bottom style sanders, in auger '13 to present with a slurry style pre-wet bar in the middle of the delivery augers in the bottom of the V-Boxes before hitting spinner.	
Montana DOT	We have moved to large volume pumps to allow for a wide range of application amounts. This allows more precise prewet control for each storm event. Calibration and more advanced technology. Changes in materials in both abrasives and chlorides. More training and better understanding of chemical capabilities	
North Dakota DOT	Yes. More acceptance since it's started. More compliance, more capability (equipment and knowledge), increased capacity. We started slow but then once people see the value and they want to do it more and seek out more equipment and capabilities. Building on that, they run out of capacity; then get more equipment; a snowball effect in a positive way.	Gradual
Oregon DOT	-	Gradual
Vermont DOT	Yes, we originally were spreading too much, now our optimal pre-wetting rate is set at 8 to 10 gallons/ton. The slurry application (high pre-wetting rates) did not work well esp. under cold temperature and built up too much on the spinner and ended up wasting the salt material. We also experimented various nozzle sizes, spray patterns, etc. in order to get uniform distribution (of the pre-wetted salt) on pavement.	Gradual

12. What changes in equipment have been made?

Table B.19. Changes in equipment.

Agency	Equipment Changes
Idaho Transportation Dept.	Liquid capacity now up to 400 gallons per truck, better pumps, variable application rates, ground speed control, went to improved mixing – wetting system
Illinois, McHenry County	All 60 – 100-gallon pre-wet tanks have been changed out to 1,000-gallon tanks with 3 snow plow trucks capable of carrying 2,600 gallons

Massachusetts DOT	addition of 100-gallon minimum saddle tank capacity, hydraulic pumps, spray nozzles, to outfit our salting trucks with pre-wetting capability
Lexington, MA	We bought slurry spreaders
Farmington Hills, MI	Improvements from drop tailgate spreaders to mostly live bottom v-boxes for better saturation of pre-wetted salt
Montana DOT	More on-board storage and bigger volume pumps. Better prewet systems with ground speed sensors
North Dakota DOT	We have larger saddle tanks, more storage capacity, more production capacity. We have tested pumping equipment but moved to gravity feed system (due to maintenance concerns). We have Tow Plows with 2,000-gallon liquid tanks and spray bars on them.
Oregon DOT	Saddle tanks and application nozzles
Vermont DOT	No major changes in equipment, mainly difference in vendors and in the type of pumps. The body, the spinner, the nozzle design are now similar between different vendors. ***** Also discussed: Vermont DOT prefers and now uses all hydraulic pumps and gave up the electric pumps, as the former enables better spreader control and the mechanics like them (no corrosion issues). The electric pumps were difficult to calibrate and had longevity/failure issues due to corrosion.

13. What was the reaction from the operations staff to the introduction of pre-wetting?

Table B.20. Staff initial reactions to pre-wetting.

Agency	Staff reactions to intro of pre-wetting?
Idaho Transportation Dept.	Varied
Illinois, McHenry County	Most initially balked as it was change but now all see the benefits
Massachusetts DOT	Some resistance, both towards the use of mag chloride and the pre-wetting practice; again due to the old story of bad experience when using mag chloride to anti-icing at warm temperature and caused slippery pavement surface condition
Lexington, MA	It doesn't work, not needed, some liked it
Farmington Hills, MI	Positive as long as level of service improved and more efficient
Montana DOT	There was some resistance in the areas until they saw the results and benefits. Then there was support and wanting the ability to prewet
North Dakota DOT	Not sure of the very initial use of them (too long ago). Likely started slow (typical at NDDOT), once getting the comfort level started to move forward. As of now, very positive experience with the pre-wetting (with liquids). Some people still have the small saddle tanks and we still encourage them to practice pre-wetting (despite the limitation on capacity). "Long-term" acceptance took a while before everybody is completely on board.
Oregon DOT	Reaction was positive as long as the level of service improved, and they could accomplish de-icing more efficiently
Vermont DOT	Some resistance initially as staff did not understand why the need to add water to salt. Encouraged the operational staff (esp. the skeptics) to give it a try and was

able to persuade the skeptics successfully.

14. Was additional training and information needed to gain their acceptance?

Table B.21. Training needed for acceptance from staff.

Agency	Additional training/info need for acceptance?
Idaho Transportation Dept.	Yes, for some but not all
Illinois, McHenry County	Yes, plus only allowing the spread systems capable of spreading only a maximum of 500 lbs/lane mile in extreme cases
Massachusetts DOT	Yes, getting better year by year
Lexington, MA Farmington Hills, MI	Yes, a lot! I believe once the staff saw surrounding communities were having success and they could get home quicker to their families, they were sold
Montana DOT	Yes, allowing them to try different applications practices and learning from what worked in certain situations and what didn't. Getting this information to others throughout the state
North Dakota DOT	We present the information we have at internal conferences, such as annual maintenance conferences (peer exchange).
Oregon DOT	Training
Vermont DOT	No

15. Was there initial resistance or skepticism from higher levels within the agency or from elected officials?

Table B.22. Resistance from high level and elected officials.

Agency	Resistance/skepticism from high levels or elected officials
Idaho DOT	
Illinois, McHenry County	We had to educate them too and continue to educate
Massachusetts DOT	Not from elected officials; but maybe some from higher levels within the agency.
Lexington, MA Farmington Hills, MI	No, only staff No
Montana DOT	Corrosion to equipment and infrastructure along with environmental issues were the biggest items to overcome
North Dakota DOT	Too long ago, not sure
Oregon DOT	Not that I am aware of
Vermont DOT	There was some skepticism from elected officials due to their concern over the corrosive effects of magnesium chloride product on equipment and motor vehicles (had to explain when used for pre-wetting instead of anti-icing, the MgCl ₂ application rate per lane mile is very limited and should not pose a corrosion issue to equipment). No skepticism from the higher levels within the agency; all supportive of pre-wetting.

16. What other obstacles or impediments did the agency face in transitioning to pre-wetting?

Table B.23. Obstacles or impediments to transitioning to pre-wetting.

Agency	Other obstacles or impediments?
Idaho Transportation Dept.	Some workers and at times equipment
Illinois, McHenry County	Educating the public but not so much with pre-wetting but our anti-icing program
Massachusetts DOT	negative opinion based on earlier misapplications of liquid mag on warm roadways
Lexington, MA Farmington Hills, MI	None, just staff skepticism As always it takes time for staff “buy in” as well as the initial harsh environment of where the outside “overhead” showering spray bar system. Depending on what direction the wind was blowing you were always sure to get overspray on your windshield and / or your mirrors that always was challenging to keep clean for visual safety.
Montana DOT	Added costs for the equipment for pre-wetting. Storage of the pre-wet materials. Are we buying a prewet material or are we going to produce the material. Logistics of producing. Additional material costs.
North Dakota DOT	Cost, equipment, capacity
Oregon DOT	Currently, age of fleet, cost
Vermont DOT	There was some skepticism from elected officials due to their concern over the corrosive effects of magnesium chloride product on equipment and motor vehicles (had to explain when used for pre-wetting instead of anti-icing, the MgCl ₂ application rate per lane mile is very limited and should not pose a corrosion issue to equipment). No skepticism from the higher levels within the agency; all supportive of pre-wetting.

17. What has been the reaction by the public to your agency’s pre-wetting operation?

Table B.24. Public reaction to pre-wetting operation per state.

Agency	Public reaction
Idaho Transportation Dept.	None
Illinois, McHenry County	Most favorable and they like our living snow fences too
Massachusetts DOT Lexington, MA Farmington Hills, MI	They are largely unaware that we pre-wet salt Positive positive with increased level of service
Montana DOT	The public is worried about corrosion and the environment
North Dakota DOT	Public is not aware of pre-wetting methods. We do not hear much from them. We hear comments about anti-icing though
Oregon DOT	None
Vermont DOT	They are mostly still NOT sold on the use of liquids (i.e., pre-wetting).

18. Did your agency publicize or otherwise inform the public and media of the use of pre-wetting?

Table B.25. Methods for informing public and media about pre-wetting.

Agency	Publicize and/or inform public and media?
Idaho Transportation Dept.	No press releases but ITD talked generally about the use of liquids
Illinois, McHenry County	We are currently getting more acclimated with using more social media
Massachusetts DOT Lexington, MA Farmington Hills, MI	No
Montana DOT	More for DLA than prewetting as well as organics
North Dakota DOT	No
Oregon DOT	We answer questions when asked
Vermont DOT	No, but we inform the public about anti-icing via flyers
	No
	Yes, we use social media, commercials, etc. for outreach

19. Has your agency revised or modified levels of service since implementing pre-wetting?

Table B.26. Modifications to levels of service per agency.

Agency	Revised or modified levels of service?
Idaho Transportation Dept.	No minimum is the same. Performance matrix requires higher level of performance. Documents sent.
Illinois, McHenry County	Our LOS has always been bare pavement ASAP after the winter event
Massachusetts DOT Lexington, MA Farmington Hills, MI	No
Montana DOT	Yes
North Dakota DOT	Yes
Oregon DOT	No
Vermont DOT	We have not revised or modified levels of service, but prewetting usually allows us to obtain the levels of service quicker
	No
	No, our interstate LOS has been bumped up one level but I don't think it was not due to the use of pre-wetting practices.

20. What is your evaluation/assessment of pre-wetting so far?

Table B.27. Evaluation of pre-wetting.

Agency	Evaluation/assessment of pre-wetting
Idaho Transportation Dept.	Good practice improves performance on materials used

Illinois, McHenry County	If you are not doing pre-wetting, you should be as there are way too many benefits
Massachusetts DOT	Awesome
Lexington, MA	It is needed to obtain our LOS w/o over-application
Farmington Hills, MI	Very good, less material used, accurate material placement and a faster start to the melting process
Montana DOT	Pre-wetting is another winter maintenance tool to add to the toolbox for our operators. It enhances material, increases performance and allows it to stay on the roadway longer. Achieves the level of service quicker.
North Dakota DOT	Positive; better salt performance (with less bounce and scatter). No quantitative assessment though. We have seen increased LOS provided to the general public but it could come from pre-wetting as well as best practices.
Oregon DOT	Effective at activating solid salt, abrasives last longer
Vermont DOT	Yes, we like it

21. What changes to pre-wetting practices/methods and materials is the agency considering?

Table B.28. Pre-wetting practices/methods or materials agencies are considering.

Agency	Changes to pre-wetting practices/methods considering?
Idaho Transportation Dept.	None at this time
Illinois, McHenry County	We are always open and looking for other ideas, especially products less harmful to the environment
Massachusetts DOT	Purchase pre-treated salt. This would cover us in areas where we are not pre-wetting sufficiently/consistently
Lexington, MA	We bought slurry spreaders and have staff refining their abilities
Farmington Hills, MI	Always looking to improve with different ways to saturate the salt, with piloting other equipment and with Adjustments to wetting blends of salt brine, of different organics and 32% Calcium chloride and other liquid deicers.
Montana DOT	None at this time
North Dakota DOT	We are experimenting with slurry application (50 gallons vs. typical 8-10 gallons per ton of solid salt). Bought a slurry box insert for one (Hudson) plow truck and been modifying Tow plow to inject liquid to make slurry. In the infancy of pushing slurry application; positive experience. Neighboring states such as Minnesota have had positive results with slurry application; integration with the Tow plow. We are playing with some homegrown systems to allow slurry application
Oregon DOT	None, other than it is required for all salt applications
Vermont DOT	Not much. Earlier we discuss the consideration of purchasing pre-wetted salt for densely populated areas but there is the high cost issue. We also need more reliable management system in the truck; current system we use is Certified Power™ and we have experienced some calibration issues

22. Other comments/insights/advice?

Montana: Be prepared to answer questions related to pre-wetting, corrosion, environmental issues. MDT is one of the only agencies requiring our deicing materials to be corrosion inhibited which also increases material cost.

Illinois: Liquid, liquid, liquid is the direction to go

Michigan: Our team will add more liquid to the pre-wetted salt with a direct application spray bar that is located on all our tandem trucks. We call it "Shake-n-Bake" This has expedited the brining process as well as de-icing for an improved LOS. Our agency likes to use liquids as another tool in our toolbox.

Lexington, MA: Don't go "all in" unless staff buys in first! Train, educate, train, education!

Additional Equipment Questions

Massachusetts DOT

1) How many spreader trucks in your fleet have on-board pre-wet capability?

Type	number	model year range
½ -3/4 ton	3	2003-2020
1-ton	8	1997-2020
Super duty (commercial class 4,5,6)	42	1993-2020
Single-axle dump (commercial class 7)	37	1982-2019
Tandem-axle dump (commercial class 8)	570	1984-2020
Tri-axle dump	876	1982-2020

2) a. What are the make/ model of all your on-board pre-wet equipment (including controllers)? Hi-Way XT3 Spreaders and Cirus Spreadsmart Controllers

b. Have you used other equipment in the past? If so, what make/ models and describe your experience/satisfaction with that equipment. Bosch Rexroth CS440/550. Satisfied but prefer Cirus

c. Have you considered other models for future purchases? If so, which ones and why? No

3) On-board pre-wet equipment maintenance and calibration

a. What maintenance is needed to keep pre-wet equipment functioning (flushing, screen cleaning, etc.)? Screen cleaning and flushing are recommended. We have reduced issues with clogging nozzles by receiving only 28% MgCl₂, which lessens KCL crystallization impacts.

b. How often do you calibrate the solid and liquid delivery systems, and how long does it take? Annually. Less than an hour per unit. Mostly commercially performed. Requirement for all Vendors to provide calibration documentation annually

4) Ground-speed of spreader vehicle: recommended vs maximum? Do you enforce a maximum speed limit? We like spreaders going 25 MPH or less. We will tolerate 30 MPH on a mainline only.

5) Does your agency utilize telematics (GPS, AVL, mobile computers, etc.) to track/ monitor application times and rates? Yes. 6 dozen full GPS/AVL units with material tracking. 1,300 telemetry-only units

North Dakota DOT

1) How many spreader trucks in your fleet have on-board pre-wet capability?

Type	number	model year range
½ -3/4 ton	0	
1-ton	0	
Super duty (commercial class 4,5,6)	0	
Single-axle dump (commercial class 7)	0	
Tandem-axle dump (commercial class 8)	350	

Tri-axle dump	0
Other	0

- 2) a. What are the make/ model of all your on-board pre-wet equipment (including controllers)? Force America Controllers.
- b. Have you used other equipment in the past? If so, what make/ models and describe your experience/satisfaction with that equipment. Yes we have tested a few different pumping systems but we moved to the complete gravity feed to reduce maintenance concerns. Topple-up Tow Plows: plum to apply liquid to the material at the spreader. Slide-in tanks with plumbing and spray bars. Some tankers with plumbing and spray bars as well.
- c. Have you considered other models for future purchases? If so, which ones and why? Slurry boxes (cost concerns). Tow Plows with liquid tanks; Bigger saddle tanks.

3) On-board pre-wet equipment maintenance and calibration

- a. How often do you calibrate the solid and liquid delivery systems, and how long does it take? Annual calibration or calibration after work done on the hydraulic system. Easy; not sure; probably less than 1 hr.

4) Ground-speed of spreader vehicle: recommended vs maximum? Do you enforce a maximum speed limit? Yes. Recommend 30 mph; but concern about rear-ending. No enforced max speed limit.

5) Does your agency utilize telematics (GPS, AVL, mobile computers, etc.) to track/ monitor application times and rates? Nothing fleet wide. But we have been testing with AVL units; also have TrackPlow for about one third of our trucks for 511 purpose. NDDOT is also in MDSS Pool Fund.

Vermont DOT

1) How many spreader trucks in your fleet have on-board pre-wet capability?

Type	number	model year range
½ -3/4 ton	0	
1-ton	0	
Super duty (commercial class 4,5,6)	3	2017
Single-axle dump (commercial class 7)	126	2012 -2020
Tandem-axle dump (commercial class 8)	118	2012 -2020
Tri-axle dump	0	

- 2) a. What are the make/ model of all your on-board pre-wet equipment (including controllers)? ProLine – controllers are Certified Power
- b. Have you used other equipment in the past? If so, what make/ models and describe your experience/satisfaction with that equipment. Tenco spreader equipment – Cyrus and Dickey John controllers. Our overall experience was good. Too many moving parts caused maintenance issues.

c. Have you considered other models for future purchases? If so, which ones and why?
 No consideration to change the current model at this time. We have an equipment committee that meets regularly to look at new products. They submit any recommendation out to the regions for their approval.

3) On-board pre-wet equipment maintenance and calibration

a. What maintenance is needed to keep pre-wet equipment functioning (flushing, screen cleaning, etc.)? Screen cleaning and flushing are recommended. In the spring, we use soapy water to flush the trucks and tanks, and then use them to clean the bridges. In the fall, we test the equipment again and identify any electrical or corrosion issues. Very rarely we may find some bad weld or rapture issue. We have 1,000-gallon tanks and tapered tanks on our (VikingTM) trucks.

b. How often do you calibrate the solid and liquid delivery systems, and how long does it take? Annually. Once a year. Less than half a day.

4) Ground-speed of spreader vehicle: recommended vs maximum? Do you enforce a maximum speed limit? We recommend truck spreaders going 25 MPH on all routes (except interstates 30 to 35 MPH) or else the beeper will go off to alert the driver. We used to recommend a maximum ground speed and that did not work well.

5) Does your agency utilize telematics (GPS, AVL, mobile computers, etc.) to track/ monitor application times and rates? Yes. We use AVL and the system is WebTec WirelessTM. We are not using MDSS. But in the near future we plan to tie in a (decision support) system into the trucks.

Idaho Transportation Department

1) How many spreader trucks in your fleet have on-board pre-wet capability?

Type	Number	Model Year Range
½ -3/4 ton	0	
1-ton	0	
Super duty (commercial class 4,5,6)	0	
Single-axle dump (commercial class 7)	80	2001- 2019
Tandem-axle dump (commercial class 8)	360	1996-2020
Tri-axle dump	2	2020

2) a. What are the make/ model of all your on-board pre-wet equipment (including controllers). CERTIFIED/CIRUS SPREADSMART RX CONTROLLERS ON ALL TRUCKS.

b. Have you used other equipment in the past? If so, what make/ models and describe your experience/satisfaction with that equipment yes varied. WENT TO CIRUS BRAND FOR STANDARDIZATION

c. Have you considered other models for future purchases? If so, which ones and why? NO WANT STANDARDIZATION, MAKING IT EASIER TO SUPPORT AVL NEEDS.

3) On-board pre-wet equipment maintenance and calibration

a. What maintenance is needed to keep pre-wet equipment functioning (flushing, screen cleaning, etc.)? ROUTINE MAINTENANCE BETWEEN STORMS INCLUDING FLUSHING, SCREEN CLEANING AND ETC IS REQUIRED FOR BEST PERFORMANCE.

b. How often do you calibrate the solid and liquid delivery systems, and how long does it take? DONE ANNUALLY IN THE FALL AND CAN BE TESTED AND UPDATED AS NEEDED. ENCOURAGED TO DO IT ONCE PER MONTH AS CIRUS CONTROLLERS HAVE THIS ABILITY.

4) Groundspeed of spreader vehicle: recommended vs maximum? Do you enforce a maximum speed limit? RECOMENDED 25 -35 MPH. MUST GO FASTER ON INTERSTATES FOR SAFETY REASONS. MUST NOT EXCEED POSTED SPEED LIMITS IN ANY CASE.

5) Does your agency utilize telematics (GPS, AVL, mobile computers, etc.) to track/ monitor application times and rates? AVL IS ON 100% OF THE FLEET. OVERALL VERY WELL LIKED. REQUIRES REGULAR MAINTENANCE TO WORK AS DESIGNED.

Montana DOT

1) How many spreader trucks in your fleet have on-board pre-wet capability?

Type	Number	Model Year Range
½ -3/4 ton		
1-ton		
Super duty (commercial class 4,5,6)		
Single-axle dump (commercial class 7)	48	1995 - 2012
Tandem-axle dump (commercial class 8)	547	1995 - 2020
Tri-axle dump		
Other Tow Plows	30	2013 – 2020

2) a. What are the make/ model of all your on-board pre-wet equipment (including controllers)? Force America SSC 1500, 5100 Ravens 710 Cirus Spreadsmart

b. Have you used other equipment in the past? If so, what make/ models and describe your experience/satisfaction with that equipment. Dicky John and Cirus. We use Cirus now - one system to work on and train on.

c. Have you considered other models for future purchases? If so, which ones and why? No. It is easier to have one system to work on and train with.

3 On-board pre-wet equipment maintenance and calibration

a. What maintenance is needed to keep pre-wet equipment functioning (flushing, screen cleaning, etc.)? Flushing tanks, summarizing, cleaning screens and nozzles, pump - flow meter and hose

b. How often do you calibrate the solid and liquid delivery systems, and how long does it take? We recommend at every 10,000 miles but require at least once a season unless you have mechanical issues

4) Groundspeed of spreader vehicle: recommended vs maximum? Do you enforce a maximum speed limit? Recommended application at 25mph with a max of 35mph and it is policy.

5) Does your agency utilize telematics? Some of our controller monitor rates and distances applied. Nothing on application times.

Illinois, McHenry County

1) How many spreader trucks in your fleet have on-board pre-wet capability?

Type	Number	Model Year Range
½ -3/4 ton		
1-ton	4	2011 – 2020
Super duty (commercial class 4,5,6)		
Single-axle dump (commercial class 7)	2	2005 – 2006
Tandem-axle dump (commercial class 8)	25	2005 – 2020
Tri-axle dump		

2) a. What are the make/ model of all your on-board pre-wet equipment (including controllers) Force 6100 for all class 7 and 8 models, Force 5100 for the 1-tons
b. Have you used other equipment in the past? If so, what make/ models and describe your experience/satisfaction with that equipment. Monroe 840 very user friendly, stopped making parts. Raven SCS4400 good initial startup system. Cirus Spreadsmart good system
c. Have you considered other models for future purchases? If so, which ones and why? We like the Force system and recently converted all equipment to them which provides operator ease of being able to jump into any piece of equipment as they are all the same

3) On-board pre-wet equipment maintenance and calibration

b. How often do you calibrate the solid and liquid delivery systems, and how long does it take? Implementing more than once per year as it takes an hour to calibrate both systems

4) Groundspeed of spreader vehicle: recommended vs maximum? Do you enforce a maximum speed limit? We recommend 25mph but it could vary between 20-30 depending on the environment. The slower the better for mechanically removing snow & ice

5) Does your agency utilize telematics (GPS, AVL, mobile computers, etc.) to track/ monitor application times and rates? Not at this time but on-board computers do track the application rates – just plug in laptop

Farmington Hills, Michigan

1) How many spreader trucks in your fleet have on-board pre-wet capability?

Type	number	model year range
------	--------	------------------

½ -3/4 ton

1-ton

Super duty (commercial class 4,5,6)

Single-axle dump (commercial class 7)	7	2006-2019
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Tandem-axle dump (commercial class 8)	10	2007-2019
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Tri-axle dump

Other Includes Single & Tandem axle Swap Loader skid attachments V-Box with Pre-wet

2) a. What are the make/ model of all your on-board pre-wet equipment (including controllers)? 15 - Rexroth systems & 2 - Storm guard systems all with pavement temperature sensors

b. Have you used other equipment in the past? If so, what make/ models and describe your experience/satisfaction with that equipment. Dickey John and Older Storm Guard system as one of our former supervisors put it “the equipment was doing its job, the team didn’t believe in it so it failed”

c. Have you considered other models for future purchases? If so, which ones and why? We demoed a “Schmidt” unit in 2015, was a challenge with existing hydraulics etc. The main operator of this unit liked the various control & placement of the spread patterns as well as the saturation of the rock salt. Our Team is always willing to consider other products for evaluation and maybe implantation.

3) On-board pre-wet equipment maintenance and calibration

a. What maintenance is needed to keep pre-wet equipment functioning (flushing, screen cleaning, etc.)? Strainers or “screens” must be checked / cleaned periodically. Our team runs a #12 or #14 mesh to allow the solids in the organics to perform without clogging up the pre-wet nozzles.

b. How often do you calibrate the solid and liquid delivery systems, and how long does it take? Calibrate every fall as well as any major hydraulic or controller issue that may affect the accuracy.

4) Groundspeed of spreader vehicle: recommended vs maximum? Do you enforce a maximum speed limit? Recommend and coach to keep speeds down 10-20 mph. DPW has not enforced a speed limit.

5) Does your agency utilize telematics (GPS, AVL, mobile computers, etc.) to track/ monitor application times and rates? _DPW team utilizes our AVL system “Skyhawk” to monitor pavement temperatures as well as progress on task etc.

Lexington, MA

1) How many spreader trucks in your fleet have on-board pre-wet capability?

Type	number	model year range
½ -3/4 ton		
1-ton		
Super duty (commercial class 4,5,6)		
Single-axle dump (commercial class 7)	8	2007 Henderson Stainless V-Box 2014-19 Schmidt Stratos
Tandem-axle dump (commercial class 8)		
Tri-axle dump	1	2015 Schmidt Strliq DLA
Other		

- 2) a. What are the make/ model of all your on-board pre-wet equipment (including controllers)? 60 GPT Schmidt Stratos, Schmidt Controllers; 6-10 VariTech Saddle Tanks, VariTech Controllers, Open Loop
- b. Have you used other equipment in the past? If so, what make/ models and describe your experience/satisfaction with that equipment.
- c. Have you considered other models for future purchases? If so, which ones and why?

3) On-board pre-wet equipment maintenance and calibration

- a. What maintenance is needed to keep pre-wet equipment functioning (flushing, screen cleaning, etc.)? Calibrate twice per season. Routine cleaning weekly, based on events
- b. How often do you calibrate the solid and liquid delivery systems, and how long does it take? Twice per season, 10 minutes per unit

4) Ground-speed of spreader vehicle: recommended vs maximum? Do you enforce a maximum speed limit? We really can't drive over 30 in town. Recommend no more than 20 mpg.

5) Does your agency utilize telematics (GPS, AVL, mobile computers, etc.) to track/ monitor application times and rates? Implementing AAT this season.

Oregon DOT

1) How many spreader trucks in your fleet have on-board pre-wet capability?

Type	number	model year range
½ -3/4 ton		
1-ton		
Super duty (commercial class 4,5,6)		
Single-axle dump (commercial class 7)		
Tandem-axle dump (commercial class 8)	135	10 Yard
Tri-axle dump		

Other

- 2) a. What are the make/ model of all your on-board pre-wet equipment (including controllers)? It varies. They are not standardized, especially on older-model 10 yard trucks
b. Have you used other equipment in the past? If so, what make/ models and describe your experience/satisfaction with that equipment.
c. Have you considered other models for future purchases? If so, which ones and why?
- 3) On-board pre-wet equipment maintenance and calibration
 - a. What maintenance is needed to keep pre-wet equipment functioning (flushing, screen cleaning, etc
 - b. How often do you calibrate the solid and liquid delivery systems, and how long does it take?
At least one per season and after any maintenance
- 4) Groundspeed of spreader vehicle: recommended vs maximum? Do you enforce a maximum speed limit? We provide training on recommended max speeds
- 5) Does your agency utilize telematics (GPS, AVL, mobile computers, etc.) to track/ monitor application times and rates? We will be in the near future.

Appendix C. Questionnaire to Manufacturers/Distributors

A. On-board Systems

1. How many of the following different sized trucks do you build equipment for?

½ -ton pickup

¾ -ton pickup

1-ton pickup or utility truck

Single-axle dump or flat-bed/ stake bed

Tandem-axle dump

Other (specify)

trailers

2. Can specification sheets be obtained for each different system? If possible, include photos and drawings.

3. What is the tank capacity (liquids) for each system?

4. Where is the tank placed onto the truck for each system?

5. What is the hopper capacity (solids) for each system?

6. What is utilized to power the pump on each different system?

7. What is the gallons-per-minute rating?

B. Optional Equipment

1. Is any optional equipment such as pumps or controllers available for each system? Please elaborate; May we obtain detailed information?

C. Calibration

1. Do you provide information and/or training on how to calibrate your equipment?

2. What equipment is required? Who do you recommend do it?

3. Once calibrated, how easy is it for the average driver to change it?

D. Applications

1. What is the range of application rates for each different system? Solids (in pounds per minute) and Liquids (in gallons per minute)?

E. Documentation

1. Can applications be tracked by the controller? Data types: GPS/AVL, rate of solids, rate of liquids, surface temperature, air temperature, camera?

F. Controller

1. What is the standard controller with each system? What abilities does it possess?

2. What optional controllers are available? What abilities does it possess?

3. Can an operator's manual be obtained for each controller?

G. Feed Mechanism

1. What is the feed mechanism that moves the solid material?

H. Weight and Material

1. What is the weight of the applicator system (empty or dry weight)?
2. What is the primary material from which the hopper is manufactured?

I. Warranty

1. What is the standard warranty available on each system?
2. Is an extended warranty available?

J. Cold Weather Operations

1. Will these liquid systems handle the thicker sugar-based products in colder weather?
2. Are there any limitations? If so, please explain.

K. Filtering

1. Do these systems filter the product being pumped? If yes:
 - a. Where is the filter—on the pump intake side or outlet side?
 - b. What typed of filter is utilized?
 - c. What is the gradation of the filter?
 - d. Is it easy to obtain a replacement, and if so, where?
 - e. How long does it take to clean and/or change? What tools are required? What skill set is required to change it?

L. Mixing

1. How is the solid material coated with the liquid?
 - a. Is it sprayed on? What type of nozzle? How many? Where are they located?
 - b. Is it mixed with the solid? How is the liquid placed into the mixing chamber? Where is the liquid placed into the mixing chamber?

M. Training and Support

1. Do you provide training with your systems?
2. What topics are covered?
3. How is it presented? If printed or electronic versions (PDFs, web-based, CD or flash drive, You Tube video) are available, may we obtain a copy?
4. What support documents are utilized or distributed as part of your training or equipment sales? If any, may we obtain a copy?
5. Does training include hands-on?
6. Do you have either a phone or website help line?
7. What addition, if any, do you believe may improve the training?

Appendix D. Manufacturer/Distributor Questionnaire answers

Manufacturer/Vendor Participants

Manufacturer/ Vendor	Contact Person	Location	Email	Website
Henderson	None provided	None provided	None provided	Hendersonproducts.com
SnowEx Wausau Equipment Co., manufactures EPOKE Material Spreaders	Bob Iverson Kurt Schallmo, Western Regional Sales Manager	Fond du Lac, WI	kschallmo@wausequipment.com	Wausauequipment.com
Monroe Truck Equipment, Inc. Hilltip Corp	Tony Beaver Craig Sandmann	Monroe, WI Lakeside Park, KY	tbeaver@monroetruck.com craig.sandmann@hilltip.com	Monroetruck.com Hilltipna.com or hilltip.com
New Leader Manufacturing (manufactures Hi- Way brand)	Mike Dean	Cedar Rapids, IA	mdean@newleader.com	https://newleader.com

Henderson

A. On-board systems

- How many of the following different sized trucks do you build equipment for?

Henderson Products manufactures equipment designed for

- 1-ton pickup or utility truck
- Single-axle dump or flat-bed/stake bed
- Tandem-axle dump
- axle dump

- Can specification sheets be obtained for each different system? If possible, include photos and drawings.

Due to the custom nature of our product, specifications can vary greatly based on customer requirements. Can product overview literature be provided which details base configurations?

- What is the tank capacity (liquids) for each system?

Liquid tank capacities vary based on equipment type and size.

Henderson First Response Anti-Ice/Granular Spreader:

100gal per linear foot. Liquid tank is integral to the unit encapsulating the sides and underside of the granular hopper.

(i.e. 13' unit = 1300g liquid capacity, 15' unit = 1500g liquid capacity)

Henderson FSH granular spreader (liquid tanks optional) (most common)

Placement of optional liquid tanks are on the underside of the hopper side slope.

On pintle chain based conveyor system, liquid is generally applied to granular material as it passes through the spinner chute

On auger-based conveyor system, liquid can either be sent to the spinner chute for pre-wetting granular materials as it passes, or optionally sent to a liquid dispensing tube above the auger for creating a slurry mixture when used with salt granular.

8-9' hopper length:

Single 75g tank (side mount to unit) (V-box)

Dual 75g tanks (150g total. Side mounted to unit, (1) each side)

Single 100g tank (side mounted to unit)

Dual 100g tanks (200gal total. Side mounted to unit, (1) each side)

10-13' hopper length

Same tank options as 8-9'

Single 200g tank (side mounted to unit)

Dual 200g tanks (400gal total. Side mounted to unit, (1) each side)

14' Hopper length or greater

Same tank options as 8-9'

Same tank options as 10-13'

Single 400g tank (side mounted to unit)

Dual 400g tanks (800gal total. Side mounted to unit, (1) each side)

Henderson Taskforce Anti-Ice/Granular Spreader

Placement of optional liquid tanks are on the underside of the hopper side slope.

The Henderson Taskforce is available in a pintle chain or auger conveyor configuration. In addition, the Taskforce includes an anti-ice spray system. Liquid can be dispensed as a pre-wetting agent to granular being passed through the spinner chute, optionally directed to a dispensing tube above the auger system for slurry mixing, or to the high output anti-icing spray boom system.

10-13' hopper length

Dual 200-gallon tanks (400-gallon total. Side mounted to unit, (1) each side)

14-16' Hopper Length

Dual 400-gallon tanks (800-gallon total. Side mounted to unit, (1) each side)

Henderson PWS Liquid System (Pre-wet system)

Dump Body Tailgate Mount (for application with pre-wetting granular material applied with an under tailgate spreader (TGS)

Installed onto the rear dump body tailgate

75-gallon tailgate mount tank

150-gallon tailgate mount tank

Dump Body In-Bed tanks

Wedge Tank liquid tanks (for rectangular shaped dump bodies/Flat floor conveyor type bodies)

Generally paired with either a under tailgate spreader and anti-ice spray system on conventional dump bodies, or as a slip in kit complete with Direct Cast spinner and anti-ice spray system on Henderson Flat Floor Munibody

Dual 260-gallon tanks (520 gallons total)

Dual 450-gallon tanks (900 gallons total)

Wedge tanks for Mark E 18" radius body

Dual 405-gallon tanks (810 gallons total)

Dump Body – External Side Mount

Designed for use on Henderson Munibody and Henderson MKE Radius (tub body).

MuniBody 22 Degree

*Single 75-gallon tank**

*Dual 75-gallon tanks**

*Single 105-gallon tank**

*Dual 105-gallon tanks**

*Single 150-gallon tank**

*Dual 150-gallon tanks**

MuniBody 35 Degree

*Single 115-gallon tank**

*Dual 115-gallon tanks**

*Single 165-gallon tanks**

*Dual 165-gallon tanks**

*Single 230-gallon tank**

*Dual 230-gallon tanks**

Mark E Radius Tub Body

*Single 60-gallon tank**

*Dual 60-gallon tanks (120-gallon total) **

*Single 100-gallon tank**

*Dual 100-gallon tank (200-gallon total) **

**Tank size dependent upon body length or hoist type and discharge type.*

Henderson Products BlackBelt Maxx (these tanks are only available for sale with a Henderson Blackbelt Maxx. (live bottom only – no hoist)

11' Unit, Dual 155-gallon tanks (310-gallon total)

12' Unit, Dual 182-gallon tanks (364-gallon total)

13' Unit, Dual 210-gallon tanks (420-gallon total)

14' Unit, Dual 237-gallon tanks (474-gallon total)

15' Unit, Dual 265-gallon tanks (530-gallon total)

16' Unit, Dual 292-gallon tanks (584-gallon total)

17' Unit, Dual 320-gallon tanks (640-gallon total)

Chassis Frame Mount

Behind the cab tank kit.

240 gallons

Side of chassis frame mount.

75 gallons

Henderson Products Liquid Anti-Icing System (LAS)

Skid frame mounted large volume liquid dispensing system for performing storm pre-treating or anti-icing activities.

925 gallon liquid tank

1065 gallon liquid tank

1235 gallon liquid tank

1635 gallon liquid tank

1800 gallon liquid tank

*other custom special order tank sizes available upon request

4. Where is the tank placed onto the truck for each system?

Tank Placement

FRS: Liquid tanks are integral to the overall unit.

FSH: Liquid tank options are saddle mounted on the sides of the granular spreader.

Taskforce: Liquid tank options are saddle mounted on the sides of the granular spreader.

PWS: (Tailgate) Tank mounts onto the outside of the dump body tailgate

PWS: (Dump Body In-Bed). Tanks mount inside of the dump body. Mounting hardware designed to allow for granular materials to be placed into the body as well.

Dump Body – External Mount:

Munibody: Tanks mounted externally to body integral platform fenders.

Mark E 18: Radius: Tanks mounted with tank brackets to the outside of the dump body sides.

Blackbelt Maxx: Tanks are externally mounted to the sides of the body unit.

LAS: Skid mounted bulk liquid tank. Frame system designed to slide into a traditional dump body.

5. What is the hopper capacity (solids) for each system?

Granular Capacity

Henderson FSH Granular Capacity (Cubic Yd Struck)				
Length (ft)	48" or 50" Sides	54" or 56" Sides	60" or 62" Sides	66" or 68" Sides
8	4.5	5.5	6.5	7.5
9	5.1	6.2	7.4	8.6
10	5.6	6.9	8.3	9.6
11	6.2	7.6	9.0	10.4
12	6.8	8.4	9.9	11.5
13	7.3	9.0	10.7	12.4
14	7.9	9.7	11.6	13.3
15	8.4	10.3	12.2	14.1
16	8.9	11.0	13.0	15

Henderson Taskforce Granular Capacity (Cubic Yd Struck)				
Length (ft)	50" Sides	56" Sides	62" Sides	68" Sides
10	5.6	6.9	8.3	9.6
11	6.2	7.6	9.0	10.4
12	6.8	8.4	9.9	11.5
13	7.3	9.0	10.7	12.4

14	7.9	9.7	11.6	13.3
15	8.4	10.3	12.2	14.1
16	8.9	11.0	13.0	15

Henderson First Response Granular Capacity (Cubic Yd Struck)	
Length (ft)	
10	5.2
11	5.8
12	6.4
13	7.0
14	7.5
15	8.1
16	8.7

Body Type	Lengths	Side Heights	Capacity (Struck)
Munibody 22deg	10' – 17'	36", 44", 52"	6.1 – 11.2
Munibody 35deg	10' – 17'	36", 44", 52"	5.4 – 9.6
Munibody Flat Floor	10' – 16'	36", 44", 52"	7.9 – 18.4

Body Type	Lengths	Side Heights (in) *	Capacity (Struck)
Mark E	9' – 20'	24,30,36,44,52,60	4.77 – 26.4
Mark E 18" Radius	10' – 18'	30, 36, 44	6.0 – 16.4

*Sloped side options also available. Side heights availability based on unit length

Body Type	Length	Capacity (Struck)
BlackBelt Maxx	11	8.45
BlackBelt Maxx	12	9.25
BlackBelt Maxx	13	10.05
BlackBelt Maxx	14	10.85
BlackBelt Maxx	15	11.65
BlackBelt Maxx	16	12.45
BlackBelt Maxx	17	13.25

6. What is utilized to power the pump on each different system?

Powering the liquid pumps are as followed:

All system that feature a basic prewet system only where liquid application is distributed at the spinner chute to pre-wet granular material prior to spreader are either ran by a 12v liquid pump, or a hydraulically driven pump which is powered by the trucks central hydraulic system Systems that feature a slurry option and/or anti-ice spray system are hydraulically driven, driven by a hydraulic pump, powered by the trucks central hydraulic system.

7. What is the gallons-per-minute rating?

Prewet system (Hydraulic)	4.1GPM
Prewet System w/Slurry (Hydraulic)	8.2GPM
Prewet System (Electric)	3.0GPM
Anti-ice System (Hydraulic)	190GPM

B. Optional Equipment

1. Is any optional equipment such as pumps or controllers available for each system? Please elaborate; May we obtain detailed information?

Henderson customizes all of our systems to meet the needs of the customer. Many options are available, too numerous to list. Most systems beyond basic prewet are going to use some type of advanced control system. These control systems are available through numerous control system manufacturers including but not limited to: Force America, Certified Power, Muncie Power, Dickey John, and many others. The offering available through these organization is vast. For operator manuals, we may need to reach out to these organizations for samples of their various control systems.

C. Calibration

1. Do you provide information and/or training on how to calibrate your equipment?

Training on system calibration is often provided by the salesperson who sold a unit to a customer and oftentimes by the hydraulic/control system provider. Basic prewet system which just wets granular material as it enters the chute can be controlled by a basic control head or a full control system. The basic control head uses a rheostat setting which outputs material based on dial setting. This information can be found in the user guide. Full control type systems require additional data sets when setting up and calibrating.

2. What equipment is required? Who do you recommend do it?

Certain systems are equipped with flow meters where the K-factor (flow meter sensor calculates speed, flow, etc.) is entered into the control system console. In addition, information such as gallons per lane mile desired are inputted into the control system. Generally, a DOT or municipality has a pre-determined gallons per lane mile they wish to achieve. Many of today's control system monitor truck speed and based on the desired gallons per lane mile and K-factor feedback, the control console will adjust liquid output.

3. Once calibrated, how easy is it for the average driver to change it?

Sample of Calibration worksheet used by McHenry County Illinois.

Location:												
Truck No:		Spreader No:										
Date:		By:										
Gate Opening (Hopper Type Spreaders) (inches)		DISCHARGE RATE (pounds discharged per mile)										
		TRAVEL SPEED AND COMPUTATION MULTIPLIER ()										
Control Setting	A Shaft RPM (Loaded)	B Discharge per Revolution (pounds)	C Discharge per Minute (b) (A x B)	5 mph (x 12.00)	10 mph (x 6.00)	15 mph (x 4.00)	20 mph (x 3.00)	25 mph (x 2.40)	30 mph (x 2.00)	35 mph (x 1.71)	40 mph (x 1.50)	45 mph (x 1.33)
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												

THE ACTUAL APPLICATION RATE (POUNDS PER LANE MILE) ON THE HIGHWAY IS THE DISCHARGE RATE DIVIDED BY THE NUMBER OF LANES BEING TREATED

SPREADER CALIBRATION PROCEDURE

Calibration is simply calculating the pounds per mile discharged for each control setting at various travel speeds by first counting the number of auger or conveyor shaft revolutions per minute, measuring the weight of salt discharged in one revolution, then multiply the two to obtain discharge per minute, and finally multiplying the discharge per minute by the time it takes to travel 1 mile. Most spreaders have multiple gate openings; so you must calibrate for specific gate openings.

Equipment needed:

1. Scale to weigh salt
2. Salt collection device
3. Marking device
4. Watch with second hand

Calibration steps:

1. Remove, by-pass or turn off spinner.
2. Warm truck's hydraulic oil to normal operating temperature with spreader system running.
3. Put partial load of salt on truck.
4. Mark shaft end of auger or conveyor.
5. Dump salt on auger.

D. Applications

1. What is the range of application rates for each different system? Solids (in pounds per minute) and Liquids (in gallons per minute)?

Application output in the snow and ice industry are generally described using lbs./lane mile for granular or gallons/lane mile for anti-icing. GPM rates can be seen in section A7 above.

Example Application Rates

Anti-Icing (brine or brine blend @ 30-40 gallons per lane mile)

Salt application 100-300 pounds per lane mile

E. Documentation

1. Can applications be tracked by the controller? Data types: GPS/AVL, rate of solids, rate of liquids, surface temperature, air temperature, camera?

As snow and ice control systems become more advanced, usage of data logging features are becoming more prevalent. These include GPS/AVL, material discharge with GPS location, air temperature, ground surface temp as well as camera operation. DOT's such as IOWA Department of Transportation have Plow Cams on many of their winter trucks.

These systems are most often provided by a hydraulic control supplier or third party.

F. Controller

1. What is the standard controller with each system?
2. What abilities does it possess?
3. What optional controllers are available? What abilities does it possess? Can an operator's manual be obtained for each controller?

Most systems beyond basic prewet are going to use some type of advanced control system. These control systems are available through numerous control system manufacturers including but not limited to: Force America, Certified Power, Muncie Power,

Dickey John, and many others. The offering available through these organization is vast. For operator manuals, we may need to reach out to these organizations for samples of their various control systems.

G. Feed Mechanism (solids)

1. What is the feed mechanism that moves the solid material?

FHS	Std & SS Pintle Chain, Roller Chain, Belt Over Chain, Single Auger, Dual Auger
Task Force	Std & SS Pintle Chain, Roller Chain, Belt Over Chain, Single Auger, Dual Auger
Munibody	Std & SS Pintle Chain, Roller Chain, Belt Over Chain, Single Auger, Dual Auger
First Response	Dual Auger
BlackBelt Maxx	Pure Belt

H. Weight and Material

1. What is the weight of the applicator system (empty or dry weight)?

Will need to assemble a product weight matrix. Base weights listed on most product literature.

2. What is the primary material from which the hopper is manufactured?

FHS and Taskforce construction are available in the following materials:

Grade 50 mild steel, 201 Stainless Steel, 304 Stainless Steel

First Response construction

304 Stainless Steel

Munibody and Dump bodies

Grade 50 mild steel, AR400 steel, 201 Stainless Steel, 304 Stainless Steel

Blackbelt Maxx

AR400, ar400/201 Stainless Steel

Liquid tanks are stainless steel

I. Warranty

1. What is the standard warranty available on each system?

Standard Warranty on Henderson provided equipment is 12months from date of delivery from dealer to end user.

2. Is an extended warranty available?

Extended warranties are available upon request. Details dependent on product and requirements.

J. Cold Weather Operations

1. Will these liquid systems handle the thicker sugar-based products in colder weather?

We have not done any performance testing with thicker sugar-based products.

Depending on viscosities of the liquid material, areas of concern where higher potential of clogging could occur would be in areas such as spray nozzle tips or filter screen.

2. Are there any limitations? If so, please explain.

Henderson does not restrict the use of thicker sugar-based products and there have been no issues with its use based on customer feedback.

K. Filtering/Screening

1. Do these systems filter or screen the product being pumped? If yes:

Liquid systems do have a filter screen to assist in removing particulates.

 - a. Is it a filter or a screen?

Serviceable Screen
 - b. Where is it located—on the pump intake side or outlet side?

Anti-icing/deicing pump uses a centrifugal pump with a filter screen on the discharge side of the pump. Gear pumps used in the lower GPM prewet pumps are gear pumps with a filter screen on the intake side.
 - c. What is the gradation of the filter or screen?
 - d. Is it easy to obtain a replacement, and if so, where?

Henderson Products liquid systems use a 40mesh screen. Henderson uses Banjo brand screen/housing. Replacements screens are available through Henderson Products or other Banjo fitting retailers. Henderson centrifugal pumps are generally able to accommodate a reasonable amount of debris.
 - e. How long does it take to clean and/or change?

Cleaning a strainer simply requires removing strainer cap, then screen and washing/brushing debris from screen.
 - f. What tools are required?

Tools required may include channel locks if filter screen cap cannot be turned by hand.
 - g. What skill set is required to change it?

Skills require to unscrew filter cap, clear filter or replace with new, install filter into housing and replace filter cap.

L. Mixing

1. How is the solid material coated with the liquid?

Mixing differs between systems.
2. Is it sprayed on? What type of nozzle? How many? Where are they located?

Pre-wetting of granular material generally takes place inside the material discharge spinner chute prior to contacting the spinner disc. Henderson's standard design uses a variable displacement orifice (VDO) inside the spinner chute. The VDO provides improved coverage with less atomization of the liquid being applied. The VDO can be best described as a hose with slits that can open/close in size based on the pressure. Henderson also has a traditional spray nozzle configuration as an alternative option. The spray nozzle option replaces the VDO kit with a (2) nozzle tip spray kit. The nozzles use a TG10 type spray tip.
3. Is it mixed with the solid? How is the liquid placed into the mixing chamber? Where is the liquid placed into the mixing chamber?

On auger spreaders with a slurry kit, a tube is installed under the granular hoppers inverted vee. The stainless tube has (6) .156 holes which spray liquid above the augers. As the augers convey material, liquid is mixed with the granular to create a slurry mixture prior to leaving the hopper.

M. Training and Support

1. Do you provide training with your systems?

Training is provided to end-users upon request.

2. What topics are covered?

Topics covered may include calibration, testing, manual/automatic modes, maintenance.

3. How is it presented? If printed or electronic versions (PDFs, web-based, CD or flash drive, You Tube video) are available, may we obtain a copy?

Due to varying system nature from truck to truck, most training is in-person based on the equipment being provided.

4. What support documents are utilized or distributed as part of your training or equipment sales? If any, may we obtain a copy?

Support documentation during the sales process primarily includes product literature. All product literature can be downloaded from the Henderson website.

5. Does training include hands-on?

Yes, see J3 above.

6. Do you have either a phone or website help line?

www.hendersonproducts.com. *Technical Services can be reached at 800-359-4970.*

7. What addition, if any, do you believe may improve the training?

Henderson training programs are comprehensive and adequately cover all necessary training requirements for each product. Additional information can be provided as needed.

Note from Dale, much information and literature available on this site.

www.hendersonproducts.com.

SnowEx

A. On-board Systems

1. How many of the following different sized trucks do you build equipment for?

½ -ton pickup

¾ -ton pickup

1-ton pickup or utility truck

Single-axle dump or flat-bed/ stake bed

Tandem-axle dump

Tri-axle dump

trailers

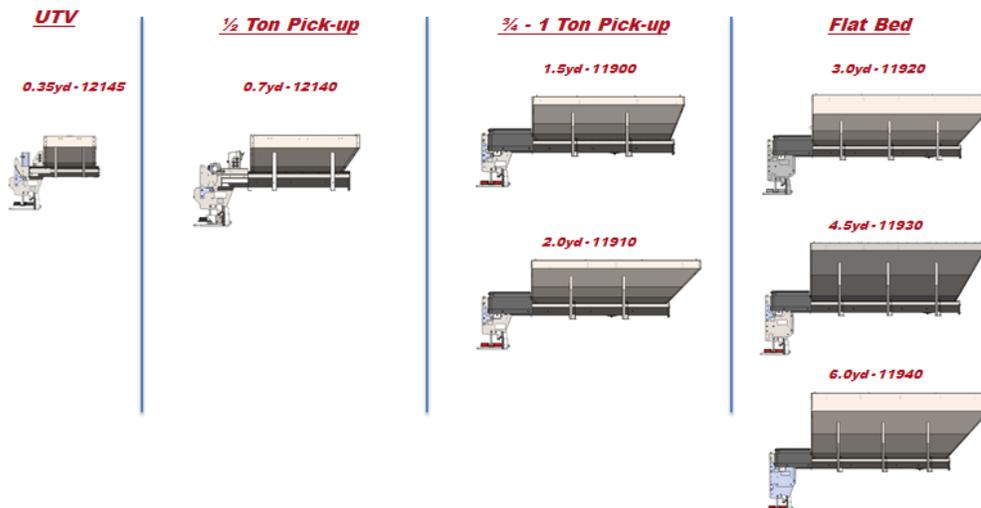
Other (specify)

SnowEx introduced in 2020 a SS line of hoppers ranging from 0.35yd to 6.0yd capacities.

This is to compliment the poly line of hoppers which is brand new for 2019 (HELIXX™).

Below is a caption that shows how the capacity sizes line up with applications.

2020 Steel Hopper Model Line-up



2. Can specification sheets be obtained for each different system? If possible, include photos and drawings.

Specifications and photos can be found on the website:

<https://www.snowexproducts.com/product/helixx-poly-hopper/>

Specifications:

[Dimensions](#) / [Operational](#) / [Electrical](#) / [Construction](#) / [Standard Equipment](#)

Imperial Metric

	11780	11790	11800	11810
Approx. Weight (Empty)	412 lb	443 lb	694 lb	718 lb
Overall Length	106"	115"	133"	133"
Overall Height	52"	59"	76"	83.5"
Overall Width	49"	49"	67.25"	67.25"
Min. Bed Length	72"	80"	98"	98"
Hopper Length	80.75"	89.75"	109"	109"
Hopper Height	34.5"	41.5"	46.5"	54"
Hopper Width	49"	49"	67.25"	67.25"

3. What is the tank capacity (liquids) for each system?

Tank capacity is 100 gallons for the 2.0yd and smaller capacities. It is comprised of (4) 25-gallon tanks. Tank capacity is 200 gallons for the larger models, with an optional 100-gallon system that can be added for a total of 300 gallons. It is comprised of (4) or (6) 50-gallon tanks.



4. Where is the tank placed onto the truck for each system?

The tanks have been designed to fit in-between the legs of the hopper.



5. What is the hopper capacity (solids) for each system?

SnowEx models that have pre-wet capability:

HELIXX Poly: 1.5yd, 2.25yd, 3.5yd & 5.0yd

HELIXX Stainless Steel: 0.7yd, 1.5yd, 2.0yd, 3.0yd, 4.5yd & 6.0yd

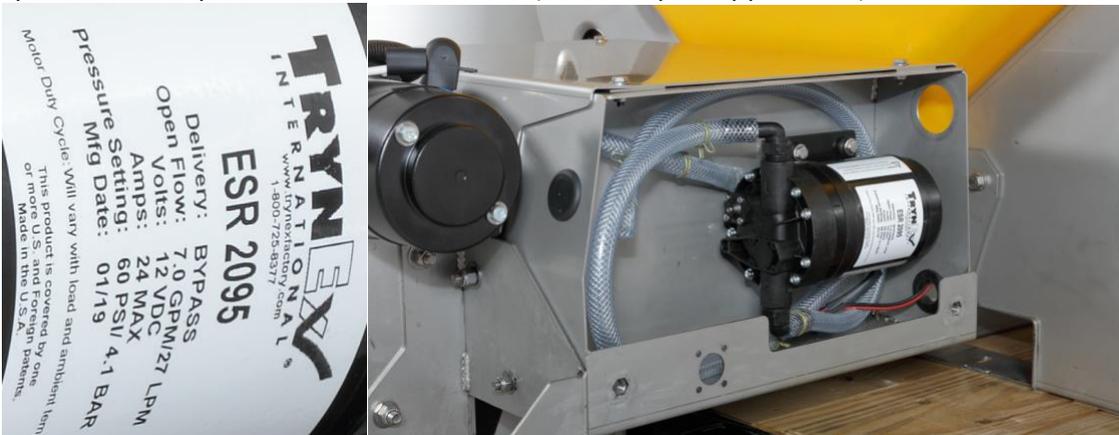
6. What is utilized to power the pump on each different system?

Each system is wired the same. Power is supplied from the vehicle battery through a fused harness kit.



7. What is the gallons-per-minute rating?

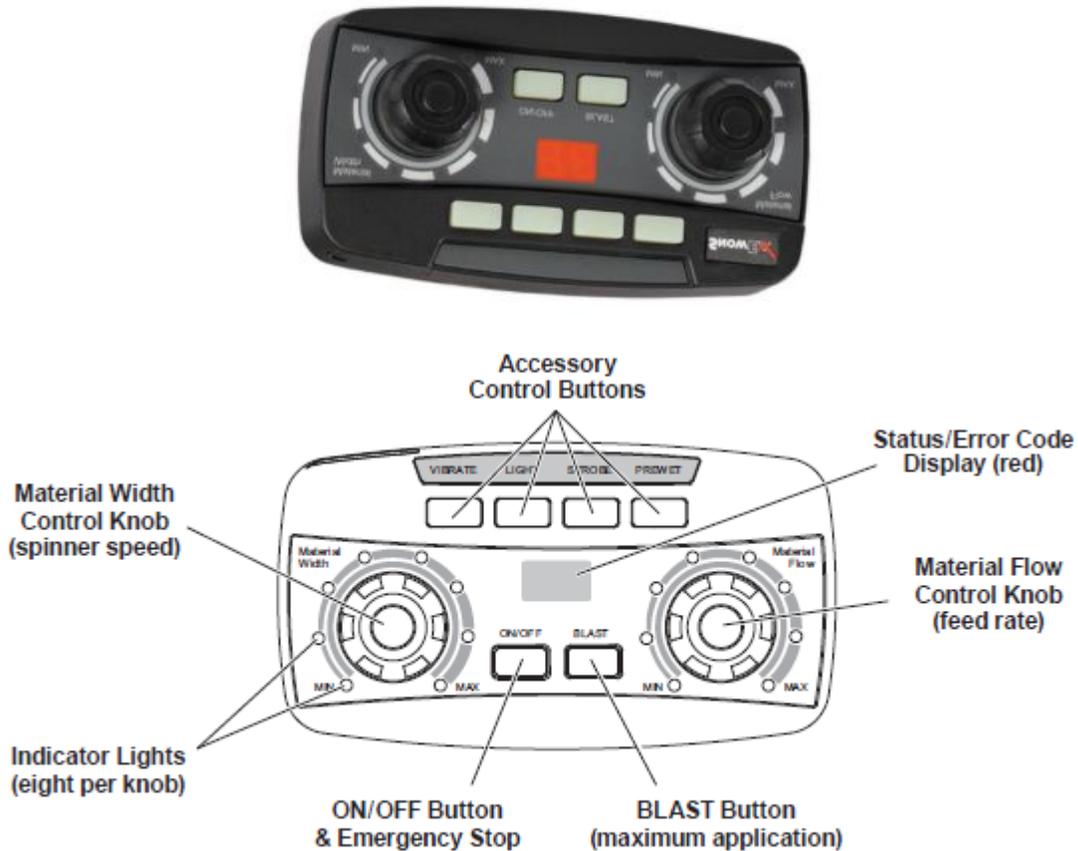
SnowEx utilizes a 7GPM pump to feed the unique “Triple Threat” capability in which it can spread solids, pre-wet the solids or DLA (Direct Liquid Application).



B. Optional Equipment

1. Is any optional equipment such as pumps or controllers available for each system? Please elaborate; May we obtain detailed information?

SnowEx hoppers as previously specified have optional pre-wetting accessory kits. The accessory kit comes with everything needed for installation and operation that isn't standard equipment for the base model hopper. The standard control is capable of operating the accessory once installed:



There are 4 buttons across the top that are utilized for accessories. When the pre-wet kit is installed, one of those buttons will light up and is back lit showing “pre-wet” as it’s designated functionality.

C. Calibration

1. Do you provide information and/or training on how to calibrate your equipment? Instructions are provided with the kit. I can provide separately.
2. What equipment is required? Who do you recommend do it?
3. Once calibrated, how easy is it for the average driver to change it?

D. Applications

1. What is the range of application rates for each different system? Solids (in pounds per minute) and Liquids (in gallons per minute)?

Included in Operating Instructions, which I can provide separately.

E. Documentation

1. Can applications be tracked by the controller? Data types: GPS/AVL, rate of solids, rate of liquids, surface temperature, air temperature, camera?

Not at this time.

F. Controller

1. What is the standard controller with each system? What abilities does it possess?

See above.

2. What optional controllers are available? What abilities does it possess?

None at this time.

3. Can an operator's manual be obtained for each controller?

Yes.

G. Feed Mechanism

What is the feed mechanism that moves the solid material?

SnowEx utilizes the patented HELIXX™ shaft-less auger system.

Helixx

- "Helixx"
- Corkscrew conveyor, shaft-less Auger
- Optimized material flow chamber
- Helixx design transfers the entire column of material
- 6.25" Inch Diameter - Variable flights 5"-7" for even unloading



H. Weight and Material

1. What is the weight of the applicator system (empty or dry weight)?

Found on website.

2. What is the primary material from which the hopper is manufactured?

Found on website.

I. Warranty

1. What is the standard warranty available on each system? 2 years

2. Is an extended warranty available? No

J. Cold Weather Operations

1. Will these liquid systems handle the thicker sugar-based products in colder weather?

Unsure. We have tested multiple types of liquids without issue.

2. Are there any limitations? If so, please explain.

K. Filtering/Screening

1. Do these systems filter or screen the product being pumped? If yes:
 - a. Is it a filter or a screen? Product comes standard with a filter.



- b. Where is it located—on the pump intake side or outlet side? Intake
- c. What is the gradation of the filter or screen? Unsure
- d. Is it easy to obtain a replacement, and if so, where? Industry standard easily obtained from any SnowEx dealer and farm supply stores.
- e. How long does it take to clean and/or change? Unsure
- f. What tools are required? Basic
- g. What skill set is required to change it? Basic

L. Mixing

1. How is the solid material coated with the liquid? Patented mixing chamber
<https://www.snowexproducts.com/product/helixx-poly-hopper/>

Watch the video to see it up close:



https://www.youtube.com/watch?v=rbsM9_yMR2g&feature=emb_logo

2. Is it sprayed on? What type of nozzle? How many? Where are they located?
3. Is it mixed with the solid? How is the liquid placed into the mixing chamber?
4. Where is the liquid placed into the mixing chamber? As you can see from the video, the spray bar distributes liquid over the top of the auger and mixes it the material before exiting the chute.

M. Training and Support

1. Do you provide training with your systems? Our Technical Support team offers hands on training for all technical dealer staff every summer before the season starts.

2. What topics are covered? Plow and spreader training. Covers operation, troubleshooting and repairs.
3. How is it presented? If printed or electronic versions (PDFs, web-based, CD or flash drive, You Tube video) are available, may we obtain a copy? In person training with actual product, presentations and hard copy books to take away.
4. What support documents are utilized or distributed as part of your training or equipment sales? If any, may we obtain a copy?
5. Does training include hands-on? Yes
6. Do you have either a phone or website help line? Tech Service “800” number for all dealers. We have a well experienced staff of over a dozen professionals that can help customers with any and all issues they may have. They travel the nation in late summer, setting up remote hands-on training for dealer technicians. In a non-covid year we train over 1000 technicians in the field.
7. What addition, if any, do you believe may improve the training? We need to provide more video training content for online viewing like YouTube.

Monroe

A. On-board Systems

1. How many of the following different sized trucks do you build equipment for?

½ -ton pickup yes_30-70-gallon prewet 225-325 direct liquid application

¾ -ton pickup yes 30-70 gallon prewet 225-325 direct liquid application

1-ton pickup or utility truck yes 30-150 gallon prewet 225-525 direct liquid

Single-axle dump or flat-bed/ stake bed yes 75-450 gallon prewet 750-1300 direct liquid

Tandem-axle dump yes 75 -1300 gallon prewet 1300 -2000 gallon direct liquid

Tri-axle dump yes 75-1300 gallon prewet 1800-2600 direct liquid application

Trailers direct liquid units 1000-6500 gallons

Other (specify)

2. Can specification sheets be obtained for each different system? Yes

What is the tank capacity (liquids) for each system?

30-1300 gallons prewet pending body size see above

225 -6500 gallons direct liquid application

Where is the tank placed onto the truck for each system? chassis frame, dump body tailgate, slip-in dump body or mounted on v-hopper sander

What is the hopper capacity (solids) for each system? 2 cubic yards – 15 cubic yards

What is utilized to power the pump on each different system? Most systems are hydraulic powered but electric is also available

What is the gallons-per-minute rating? 1-6 gpm electric driven pumps prewetting 1-10 gpm hydraulic driven pumps prewetting 75-210 gpm direct liquid application

B. Optional Equipment

Is any optional equipment such as pumps or controllers available for each system? Please elaborate; May we obtain detailed formation?

Open loop systems Monroe supplies simple controller. Closed loop controls would be supplied by Force America, Certified Power, Dickey John, Rexroth, Parker, Cirrus etc.

C. Calibration

Do you provide information and/or training on how to calibrate your equipment? We offer in house training or on-site training for Force America controls. Other brands of controllers we rely on their factory sales staff

What equipment is required? Who do you recommend do it? weight scale, catch tubs, graduated gallon container

Once calibrated, how easy is it for the average driver to change it? Calibration is typically only changed by management

D. Applications

What is the range of application rates for each different system? (Solids in pounds per minute and Liquids in gallons per minute)? Solids are typically called out in pounds per lane mile and liquid is called out in gallons per ton of granular product. Granular product can range from 100 - 2000 pounds per lane mile pending 100% salt, salt/sand mix, 100% sand. Liquid will typically be from 10 -75 gallons per ton of granular.

E. Documentation

Can applications be tracked by the controller? (Data types: GPS/AVL, rate of solids, rate of liquids, surface temperature, air temperature, camera?) **Many controllers do have data recording capabilities. All pending make/mode**

F. Controller

1. What is the standard controller with each system? What abilities does it possess? Varies by customer Certified Power, Force America, Cirus and Rexroth are primary suppliers. Major of controllers are ground speed orientated with data recording capabilities.
2. What optional controllers are available? What abilities does it possess? Monroe does not manufacture any controllers - we rely on suppliers mentioned above
3. Can an operator's manual be obtained for each controller? **Many available on-line from suppliers website**

G. Feed Mechanism

1. What is the feed mechanism that moves the solid material? **Pintle style drag chain or auger(s)**

H. Weight and Material

1. What is the weight of the applicator system (empty or dry weight)? **500 lbs. to 8000 lbs. pending size of unit (empty).**
2. What is the primary material from which the hopper is manufactured? **Stainless steel**

I. Warranty

1. What is the standard warranty available on each system? **12 months from date of in-service**
2. Is an extended warranty available? **_yes pending contract**

J. Cold Weather Operations

1. Will these liquid systems handle the thicker sugar-based products in colder weather? Yes, hydraulic driven gear pumps are better than the electric pumps for this prewetting application. Most direct liquid applicators utilize centrifugal pumps
2. Are there any limitations? If so, please explain. Product viscosity and temperature can affect ability to be sprayed

K. Filtering/Screening

1. Do these systems filter or screen the product being pumped? If yes:
Is it a filter or a screen? **y-style filter is standard**
Where is it located—on the pump intake side or outlet side? **intake side of pump**
What is the gradation of the filter or screen? **20 mesh**
- d. Is it easy to obtain a replacement, and if so, where? **distributor or local farm store**
- e. How long does it take to clean and/or change? **30 seconds**
- f. What tools are required? **no tools required**

g. What skill set is required to change it? **very minimal**

L. Mixing

1. How is the solid material coated with the liquid? **Either sprayed on or injected**

2. Is it sprayed on? What type of nozzle? How many? Where are they located? Yes, sprayed on, fan style nozzle, 103 nozzles, 103 gpm per nozzle pending system

3. Is it mixed with the solid? How is the liquid placed into the mixing chamber? **Injected – ¾” stainless pipe in auger through (typical)**

4. Where is the liquid placed into the mixing chamber? **Same as above.**

M. Training and Support

Do you provide training with your systems? Via distributor or regional salesman. What topics are covered? Typical application rates, travel speeds, calibration and general maintenance.

How is it presented? If printed or electronic versions (PDFs, web-based, CD or flash drive, YouTube video) are available, may we obtain a copy? **Typically on-site, no video available**

What support documents are utilized or distributed as part of your training or equipment sales? If any, may we obtain a copy? **Literature attached**

Does training include hands-on? **Yes, on-site**

Do you have either a phone or website help line? Yes, two in-house service techs to help with hydraulics and Force America Controls

What addition, if any, do you believe may improve the training?

Epoke

A. On-board Systems , Make EPOKE MATERIAL SPREADERS

1. How many of the following different sized trucks do you build equipment for?

½ -ton pickup

¾ -ton pickup

1-ton pickup or utility truck **X**

Single-axle dump or flat-bed/ stake bed **X**

Tandem-axle dump **X**

Tri-axle dump **X**

Trailers **X**

Other (specify) Custom Chassis

2. Can specification sheets be obtained for each different system? *Yes, Spec Sheets attached.*

If possible, include photos and drawings.

3. What is the tank capacity (liquids) for each system? We can provide tank configurations from 500 gallons to 1,765 gallons

4. Where is the tank placed onto the truck for each system? Tanks are typically placed on the truck behind the cab with weight distributed equally over chassis. This is done by using saddle tanks and tanks in front of the solid material hopper.

5. What is the hopper capacity (solids) for each system? Various hopper sizes are available from 4 cu. yds. To 12 cu yards.

6. What is utilized to power the pump on each different system? There are various ways available to provide required hydraulic power to the pump(s) including chassis hydraulic system (PTO), Drive wheel and Independent diesel engine.

What is the gallons-per-minute rating? *Maximum GPM of liquid is 78 GPM (4902SH)*

B. Optional Equipment

Is any optional equipment such as pumps or controllers available for each system? Please elaborate; May we obtain detailed formation? *See attached documentation and literature.*

C. Calibration

1. Do you provide information and/or training on how to calibrate your equipment? *Yes, formal training on calibration is provided at time of delivery. Detailed calibration procedure is also documented in instruction/operations manuals*

2. What equipment is required? Who do you recommend do it? *No specialized tools required. Items required: Scale, heavy-duty plastic bag. Calibration can be done by anyone assigned the responsibility both mechanics and operators*

3. Once calibrated, how easy is it for the average driver to change it? Calibration is password protected in the program. No one can change calibration unless they have a password.

D. Applications

What is the range of application rates for each different system? (Solids in pounds per minute and Liquids in gallons per minute)? *Solids weight varies based on material weight. 0 to 992 lbs. per minute max (sand) Liquids will also vary based on weight of material 0-78 GPM*

E. Documentation

Can applications be tracked by the controller? (Data types: GPS/AVL, rate of solids, rate of liquids, surface temperature, air temperature, camera?) *Yes, Epoke has the ability to collect data, monitor routes, surface and air temp, material distributed etc. through EpoTrack, EpoSat, EpoData and EpoTherm.*

F. Controller

1. What is the standard controller with each system? What abilities does it possess? Full control, adjustment and monitoring of material spreader is accomplished using the EpoMaster X-1 controller. Available both in a hardwired and wireless version Options available include EpoSAT, EpoTrack and Data Collection

2. What optional controllers are available? What abilities does it possess? *Available in an EpoMini X-1 controller.*

3. Can an operator's manual be obtained for each controller? *Operator's manuals for each are available.*

G. Feed Mechanism

What is the feed mechanism that moves the solid material? Epoke material spreaders use the "Epoke Principle" which includes an agitator in the hopper to help break down the material being supplied to the delivery roller. The delivery roller then meters the material allowing it to move to the conveyor or auger and ultimately to the spinner for distribution to the surface being treated.

H. Weight and Material

1. What is the weight of the applicator system (empty or dry weight)? Empty or dry weight will vary depending on size and configuration of the material spreader and its distribution system.

2. What is the primary material from which the hopper is manufactured? Primary material of the hopper is steel which is then sandblasted, treated with zinc primer and then painted. Epoke then backs it with a 10-year rust through guarantee.

I. Warranty

1. What is the standard warranty available on each system? *Standard warranty is 1-year parts and labor.*

2. Is an extended warranty available? Extended warranty and service contracts (including preventative maintenance programs) are available.

J. Cold Weather Operations

1. Will these liquid systems handle the thicker sugar-based products in colder weather? The liquid system and pumps are designed to distribute many types of liquids of varying viscosities. Can be used with liquids with viscosities of up to 3.2 mPa.s Proper maintenance, calibration and cleaning is required.

2. Are there any limitations? If so, please explain. Can be used with liquids with viscosities of up to 3.2 mPa.s No limitations as long as liquid is not being applied at or below its freeze point.

K. Filtering/Screening

1. Do these systems filter or screen the product being pumped? If yes: *Yes*

2. Is it a filter or a screen? *Filter and screen*

3. Where is it located—on the pump intake side or outlet side? *Pump intake*

4. What is the gradation of the filter or screen? *N/A*

5. Is it easy to obtain a replacement, and if so, where? *Yes, Wausau Equipment*

6. How long does it take to clean and/or change? *5 minutes*

7. What tools are required? *Filter wrench*

8. What skill set is required to change it? *None, ability to use basic hand tools*

L. Mixing

1. How is the solid material coated with the liquid? Depending on how the spreader is configured it can be coated in the funnel (drop tube), on the spinner, mixing chamber or as it is disbursed on the surface.

2. Is it sprayed on? What type of nozzle? How many? Where are they located? Nozzles are located either in the funnel (drop tube) just above the mixing chamber or on the back of the unit (4902) size and quantity of nozzles varies based on location.

3. Is it mixed with the solid? How is the liquid placed into the mixing chamber? Solid material is gravity fed to mixing chamber while solid is pumped in simultaneously.

4. Where is the liquid placed into the mixing chamber? *From a nozzle directly above the mixing chamber.*

M. Training and Support

1. Do you provide training with your systems? Yes, full training is provided upon delivery of equipment.

2. What topics are covered? Operation, Calibration, Preventive Maintenance, Seasonal Maintenance, General Maintenance and Troubleshooting.

3. How is it presented? If printed or electronic versions (PDFs, web-based, CD or flash drive, You Tube video) are available, may we obtain a copy? *Training and support is provided in all versions noted (Classroom, PDFs, web-based, CD or flash drive, You Tube video) (available upon request)*

4. What support documents are utilized or distributed as part of your training or equipment sales? If any, may we obtain a copy? *Operations, Maintenance manuals, Troubleshooting guides and PDF presentations (available upon request)*

5. Does training include hands-on? Yes, both hands on and classroom training is available

6. Do you have either a phone or website help line? Yes, Technical support is provided by contacting the Wausau 24-hour service line parts and support is also available by contacting epoke.dk

7. What addition, if any, do you believe may improve the training? By providing both classroom and hands-on training it allows the environment to be interactive giving the attendees the opportunity to be involved, asking questions and actually working with the equipment.

Hilltip Corp

A. On-board Systems

1. How many of the following different sized trucks do you build equipment for?

½ -ton pickup	X
¾ -ton pickup	X
1-ton pickup or utility truck	X
Single-axle dump or flat-bed/ stake bed	X
Tandem-axle dump	
Tri-axle dump	
Trailers	X
Other (specify)	UTVs, tractors, skid steers, tool carriers

2. Can specification sheets be obtained for each different system? If possible, include photos and drawings. *Yes*

3. What is the tank capacity (liquids) for each system? *Varies depending on size of spreader/sprayer. On the low end 87 gallons; on the high end 550 gallons.*

4. Where is the tank placed onto the truck for each system? *For all Hilltip spreaders, the tanks are built into the hopper of the spreader and are installed in the same place as the spreader. For the sprayers, the tanks are mounted to a framework that is mounted to the truck*

5. What is the hopper capacity (solids) for each system? *Varies; our smallest unit holds 4.5 ft.³ of solid material and our largest machine handles 6.0³*

6. What is utilized to power the pump on each different system? *Electric motors*

7. What is the gallons-per-minute rating? *7 gallons per minute/per pump. If users for a pre-kit and spraybar, machines are fitted with (2) pumps.*

B. Optional Equipment

Is any optional equipment such as pumps or controllers available for each system? Please elaborate; May we obtain detailed formation? *Yes, we offer 2-way GPRS tracking systems, prewet kits, spray bars, hose reels, strobes, lights, bladders, leg stands, extended chutes, and material alarms and asymmetry adjustments. Information is available on our options.*

C. Calibration

1. Do you provide information and/or training on how to calibrate your equipment? *Yes, information is available on calibration on the controller itself and through training with factory re presentation.*

2. What equipment is required? Who do you recommend do it? No specific equipment is required other than a means of capturing/weighing material and a measure device to gauge.

3. Once calibrated, how easy is it for the average driver to change it? Moderately difficult. The driver would have to know the procedure to get into the calibration screens on the controller and have authority to override it.

D. Applications

What is the range of application rates for each different system? (Solids in pounds per minute and Liquids in gallons per minute)? *335 lbs/minute* 12.25 lbs/1000 ft** 850 lbs/lane mile. The pumps run at 7 gallons per minute.*

E. Documentation

Can applications be tracked by the controller? (Data types: GPS/AVL, rate of solids, rate of liquids, surface temperature, air temperature, camera?) *Yes. Only Hilltip offers a 2-way GPRS tracking system allowing users to remotely change application and spinner rates from any device in the world. Our system also allows detailed reporting of all spreading metrics and geo-fencing capability for worksites to allow application rates per worksite, which helps limit the impact of salt/brine on the environment.*

F. Controller

1. What is the standard controller with each system? What abilities does it possess? All Hilltip spreaders with the exception of our tailgate units come with our StrikeSmart controller. These controllers are equipped with ground speed control and manual operating modes allowing the spreader to start and stop when the vehicle starts and stops. All optional equipment wired through the spreader can be controlled through this controller as well. Any worksite created in HTrack is also visible on the controller.

2. What optional controllers are available? What abilities does it possess? Hilltip offers no optional controllers. Our small spreaders utilize a smart phone we provide with our StrikeSmart control app preloaded so the user can control the machine via a Bluetooth link. All functions of StrikeSmart controllers are available in the app.

3. Can an operator's manual be obtained for each controller? *Yes, conditionally*

G. Feed Mechanism

What is the feed mechanism that moves the solid material? *Your choice of auger, chain, or conveyer belt.*

H. Weight and Material

1. What is the weight of the applicator system (empty or dry weight)? *Varies on size of machine. The lightest unit is 128 lbs and the heaviest is 1200 lbs.*

2. What is the primary material from which the hopper is manufactured? *Hi-mil polyethylene*

I. Warranty

1. What is the standard warranty available on each system? *2 years from date of purchase*
2. Is an extended warranty available? *Yes, on a negotiated basis*

J. Cold Weather Operations

1. Will these liquid systems handle the thicker sugar-based products in colder weather? Yes, Hilltip products are built in northern Finland and are designed to handle a wide variety of liquid materials in cold temperatures including pesticides, fire retardants, sanitizers, fertilizers, brine, and sealants.
2. Are there any limitations? If so, please explain. The limitations to liquid applications depend on the viscosity of the liquid. The more dense the material, the more difficult it is for the pumps

K. Filtering/Screening

1. Do these systems filter or screen the product being pumped? If yes:
 - a. Is it a filter or a screen? *Yes*
 - b. Where is it located—on the pump intake side or outlet side? *Each pump; inlet side*
 - c. What is the gradation of the filter or screen? *Stainless mesh*
 - d. Is it easy to obtain a replacement, and if so, where? *Yes, available through authorized distributors*
 - e. How long does it take to clean and/or change? *Less than 2 minutes*
 - f. What tools are required? *None*
 - g. What skill set is required to change it? *No skills required*

L. Mixing

1. How is the solid material coated with the liquid? The pump sprays solid material as it leaves the end of the auger and heads down the chute. Some users will spray the material at the spinner
2. Is it sprayed on? What type of nozzle? How many? Where are they located? *Yes, material is sprayed with (2) fan style nozzles in the upper chute assembly*
3. Is it mixed with the solid? How is the liquid placed into the mixing chamber? *Liquid material is pumped into the tank via a 2" inlet pipe and an external electric or gas pump. The liquid is kept separate from the solid material.*
4. Where is the liquid placed into the mixing chamber? *Liquid is stored in built-in tanks in the hopper. It mixes with solids at the end of the auger or at the spinner. Brine making – bulk material and liquid are mixed in a tank and circulated with 102 GPM pump.*

M. Training and Support

1. Do you provide training with your systems? *Yes*
2. What topics are covered? *Everything from proper operation, maintenance, storage to software training for HTrack, worksite creation and snow/ice mitigation strategies.*
3. How is it presented? If printed or electronic versions (PDFs, web-based, CD or flash drive, You Tube video) are available, may we obtain a copy? *Training is provided in-person or virtually and augmented with product manuals. Manuals can be provided conditionally.*

4. What support documents are utilized or distributed as part of your training or equipment sales? If any, may we obtain a copy? *Owner/operator manuals, service manuals and parts manuals are provided with the equipment. Yes, conditionally.*
5. Does training include hands-on? *Yes, by customer demand*
6. Do you have either a phone or website help line? Distributors are the first line of assistance and they have access to distributor portal with information covering all our machines. Hilltip also provides access to us directly via phone or email.
7. What addition, if any, do you believe may improve the training? Operator ride-alongs during real-time snow events that can better demonstrate the functionality and the real time responsiveness of our systems.

Any additional comments/information

Hilltip manufactures the most technologically advanced spreaders and sprayers in the world in their class and are designed to help users save time and money while reducing the negative impact of salt and brine on the environment. Our machines help take the human element out of ice control operations that allow for greater safety of the operator and high levels of documentation to demonstrate contractual responsibility and help with insurance claims.

New Leader Manufacturing

A. On-board Systems, Make: Hi-Way

1. How many of the following different sized trucks do you build equipment for?

½ -ton pickup

¾ -ton pickup X

1-ton pickup or utility truck X

Single-axle dump or flat-bed/ stake bed X

Tandem-axle dump X

Tri-axle dump X

Trailers

Other (specify)

2. Can specification sheets be obtained for each different system? Yes, they are available
If possible, include photos and drawings.

3. What is the tank capacity (liquids) for each system? Capacity (liquid) for each type of
system is as follows:

Tailgate spreader system – 100-gallon single tank

Vee Box Spreader System / standard – 75-gallon single or dual tank system, 100-gallon
single or dual tank system.

Vee Box Spreader System / Slurry Machine – 232-gallon each dual system (464-gallon total),
300-gallon each dual tank system (600-gallon total), 362-gallon each dual tank system (724-
gallon total) and one 400-gallon vee box insert tank for the slurry system that works in
conjunction with the 724-gallon system to provide 1100 gallon of liquid.

Multi-purpose body systems – 65-gallon fender mounted tank (can be mounted on one or
both fenders), 95-gallon fender mounted tank (can be mounted on one or both fenders),
200-gallon and 300-gallon sub-frame mounted systems and 900-gallon to 1400-gallon body
insert systems.

4. Where is the tank(s) placed onto the truck for each system?

On a tailgate spreader the tank is mounted on the dump body tailgate

On a vee box spreader, the tanks are mounted on the side of the body

On a multi-purpose body, the tanks are mounted; 1) on the body fenders or, 2) on a
subframe located under the multi-purpose body or, 3) inside of the body (reduces granular
capacity).

5. What is the hopper capacity (solids) for each system?

On a tailgate spreader system, the granular capacity is dependent upon the size of the
dump body.

On a vee box spreader, the granular capacity is again dependent upon the size of the body.
Our vee boxes have capacities (struck) starting at 5 cubic yards and going to as much as 12
cubic yard capacity. On slurry style units the higher capacity of the liquid reduces the
granular capacity to the range of 5 cubic yards to 8 cubic yards (struck) capacity.

On multi-purpose bodies, the granular capacity with fender mounted tanks or sub-frame
mounted tanks the granular capacity ranges from 8 cubic yard to 17 cubic yard depending
upon the length of the body. With the insert tanks the granular capacity is cut by about 40%

6. What is utilized to power the pump on each different system?

Pre-wet systems offered can be powered by either 12-volt electric or by the trucks central hydraulic system.

7. What are the gallons-per-minute rating?

On a standard style pre-wet system, the pump output is 3.3 GPM to 10 GPM.

On a slurry type machine, the pump output is 15 GPM to 25 GPM

B. Optional Equipment

Is any optional equipment such as pumps or controllers available for each system? Please elaborate; May we obtain detailed formation? – While a pre-wet system can be purchase with a control for the system, it is typical for the control of the system to be “within” the control system for the hydraulic package of the truck. This is the system that controls the plow functions, spreader functions, pre-wet functions and if so equipped, anti-icing functions. It is rare, other than retrofitting an older truck, to have a control only for the pre-wet system. As far as optional attachments to the various systems, we do not offer any.

C. Calibration

1. Do you provide information and/or training on how to calibrate your equipment? – Yes, that information is provided in the Operation Manual(s)

2. What equipment is required? Who do you recommend do it? – To calibrate a product is normally pretty easy. A stopwatch, some hand tools, a five-gallon bucket and a scale are all that is required. The agency involved typically dictates who is in charge of calibration, some have the operators, some prefer the mechanics.

3. Once calibrated, how easy is it for the average driver to change it? This depends upon the entity that owns the product. Some agencies require a password to modify the program as established and some do not. It is easy for an operator to modify the program if that is the policy of the agency involved. Now if you are asking can an operator change the application amount? The answer, as stated previously, depends upon the type of controller. In manual mode the operator typically has a number of settings that can be used to increase the amount applied of granular and liquid.

D. Applications

1. What is the range of application rates for each different system? (Solids in pounds per minute and Liquids in gallons per minute)? Granular – low end = 65 pounds / min – high end

E. Documentation

Can applications be tracked by the controller? (Data types: GPS/AVL, rate of solids, rate of liquids, surface temperature, air temperature, camera?) - If set up with the **proper** control system the applications can be tracked.

F. Controller

1. What is the standard controller with each system? What abilities does it possess? – Most agencies we deal with today are purchasing a controller that is capable of the following functions:

Plow – all functions

Spreader – Granular

Spreader – Liquid (pre-wet)

Dump body – up / down / tailgate latch

Data logging

2. What optional controllers are available? What abilities does it possess? – Optional “features” of controllers would include:

Tow plow operation

Road Temperature sensors

Anti-icing function

Communication ability – cellular or wi-fi

Other

3. Can an operator’s manual be obtained for each controller? – These types of manuals would need to come from the suppliers of the control system. Companies supplying these types of product would include (but are not limited to):

Bosh Rexroth

Certified Power / Cirus Controls

Force America

Muncie Hydraulics

G. Feed Mechanism

1. What is the feed mechanism that moves the solid material? – The feed mechanism will be 1) conveyor chain (bar flight), Belt over chain (belting riveted to a bar flight chain for more precise application), or auger (single or dual).

H. Weight and Material

1. What is the weight of the applicator system (empty or dry weight)? – For Granular systems, the weight varies by application method:

Tailgate Spreader – approximately 500 pounds

Vee Box Spreader – Weight determined by length and steel gauges – 1,900 to 5,000 pounds

Multi-purpose body – 3,800 to 5,500 pounds

If you are speaking of liquid systems, the weight can range from 200 pounds to 2,000 pounds.

2. What is the primary material from which the hopper is manufactured? – In our instance the material is steel. The type of steel can be Carbon, 409 stainless steel, 201 stainless steel or 304 stainless steel.

I. Warranty

1. What is the standard warranty available on each system? Warranty period for Hi-Way product is 13 Months from date of registration.

2. Is an extended warranty available? – Yes, an extended warranty can be provided.

J. Cold Weather Operations

1. Will these liquid systems handle the thicker sugar-based products in colder weather? – We do not have experience with these types of liquid on the electric systems. My thoughts are that they would not work well. On hydraulic pumps both standard and slurry type, we have had no issues.

2. Are there any limitations? If so, please explain.

K. Filtering/Screening

1. Do these systems filter or screen the product being pumped? If yes:

Is it a filter or a screen? – Screen type filtration

Where is it located—on the pump intake side or outlet side? – Pump intake side

What is the gradation of the filter or screen? 30 to 50 mesh / depending upon unit

Is it easy to obtain a replacement, and if so, where? Yes – through our parts department.

How long does it take to clean and/or change? - 5 minutes

What tools are required? – Caps are normally hand tightened. Spanner wrench can be used if needed

g. What skill set is required to change it? - minimal

L. Mixing

1. How is the solid material coated with the liquid? – There are two methods of coating the material; 1) Spray nozzle, and 2) Blended.

2. Is it sprayed on? What type of nozzle? How many? Where are they located? – if the liquid is sprayed on it can be applied at the conveyor just prior to exiting into the spinner chute or within the spinner chute. The nozzle(s) are typically a “flat fan” type with the quantity being 2 to 4. This is a typical application for a “chain conveyor” type machine.

3. Is it mixed with the solid? How is the liquid placed into the mixing chamber? – On auger machines the material is pumped into the conveyor system in between the augers. The counter rotation of the augers is used to mix the material with the liquid. On slurry style machines the liquid is deposited through a diffuser onto the spinner disc in the same area as the granular. A special designed hub and spinner disc “mix” or “blend” the material to provide an even coating of the liquid onto the granular.

4. Where is the liquid placed into the mixing chamber? – see answers to questions 1 - 3

M. Training and Support

Do you provide training with your systems? Yes – through dealer training or factory assisted dealer training.

What topics are covered? Topics typically include: Calibration, operation and required / recommended service.

How is it presented? If printed or electronic versions (PDFs, web-based, CD or flash drive, You Tube video) are available, may we obtain a copy?

What support documents are utilized or distributed as part of your training or equipment sales? If any, may we obtain a copy? Training is provided through PowerPoint – manuals accompany product

Does training include hands-on? Yes, we prefer to do classroom followed up by machine time with our dealers attending.

Do you have either a phone or website help line? – Operation and parts manuals are offered through our online website. Service is provided by our dealer network

What addition, if any, do you believe may improve the training? - none.



research for winter highway maintenance

Lead state:

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